NFPA 86D

Standard for Industrial Furnaces Using Vacuum as an Atmosphere

1999 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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NFPA 86D

Standard for

Industrial Furnaces Using Vacuum as an Atmosphere

1999 Edition

This edition of NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*, was prepared by the Technical Committee on Ovens and Furnaces and acted on by the National Fire Protection Association, Inc., at its May Meeting held May 17–20, 1999, in Baltimore, MD. It was issued by the Standards Council on July 22, 1999, with an effective date of August 13, 1999, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 86D was approved as an American National Standard on August 13, 1999.

Origin and Development of NFPA 86D

With the increased use of vacuum furnaces in industry, a sectional committee under the Committee on Ovens and Furnaces was organized in 1974 to prepare a standard covering Class D Furnaces. The first edition was adopted by the Association at the 1976 NFPA Fall Meeting. Editorial revisions were made in the 1978 edition. The 1985 edition included a complete rewrite of the foreword, the development of a new Chapter 12 for mandatory referenced publications, and a revision of Appendix F.

The 1990 edition was a complete revision that incorporated a variety of technical and editorial changes, including a new Appendix A, and consolidated appendix information in accordance with the NFPA *Manual of Style*.

The 1995 edition of NFPA 86D provided correlation with NFPA 86, *Standard for Ovens and Furnaces*, and NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*. It also refined and updated the standard to more current technologies, provided increased requirements in several areas, and expanded the explanatory material in the appendixes.

This edition of NFPA 86D includes changes to the technical requirements in several areas. Also included are many refinements to clarify the technical requirements. Changes are also provided to more clearly distinguish mandatory requirements from nonmandatory recommendations and explanatory material. Nonmandatory notes have been relocated into the appendixes.

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on control of fire and explosion hazards in drying ovens for japan, enamel, and other finishes, bakery ovens, core ovens, annealing and heat treating furnaces, and other special atmosphere furnaces, including equipment for other special atmospheres.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

Information on referenced publications can be found in Chapter 13 and Appendix G.

FOREWORD

Explosions and fires in fuel-fired and electric heat utilization equipment constitute a loss potential in life, property, and production. This standard is a compilation of guidelines, rules, and methods applicable to the safe operation of this type of equipment.

There are other conditions and regulations not covered in this standard, such as toxic vapors; hazardous materials; noise levels; heat stress; and local, state, and federal regulations (EPA and OSHA), that should be considered when designing and operating furnaces.

Causes of practically all failures can be traced to human error. The most significant failures include inadequate training of operators, lack of proper maintenance, and improper application of equipment.

Users and designers must utilize engineering skill to bring together that proper combination of controls and training necessary for the safe operation of the equipment. This standard classifies furnaces as follows.

Class A ovens and furnaces are heat utilization equipment operating at approximately atmospheric pressure wherein there is a potential explosion or fire hazard that could be occasioned by the presence of flammable volatiles or combustible materials processed or heated in the furnace.

Such flammable volatiles or combustible materials can, for instance, originate from any of the following: (1) paints, powders, inks, and adhesives from finishing processes, such as dipped, coated, sprayed, and impregnated materials; (2) substrate material; (3) wood, paper, and plastic pallets, spacers, or packaging materials; or (4) polymerization or other molecular rearrangements.

Potentially flammable materials, such as quench oil, waterborne finishes, cooling oil, or cooking oils, that present a hazard are ventilated according to Class A standards.

Class B ovens and furnaces are heat utilization equipment operating at approximately atmospheric pressure wherein there are no flammable volatiles or combustible materials being heated.

Class C ovens and furnaces are those in which there is a potential hazard due to a flammable or other special atmosphere being used for treatment of material in process. This type of furnace can use any type of heating system and includes a special atmosphere supply system(s). Also included in the Class C classification are integral quench furnaces and molten salt bath furnaces.

Class D furnaces are vacuum furnaces that operate at temperatures above ambient to over 5000°F (2760°C) and at pressures from vacuum to several atmospheres during heating using any type of heating system. These furnaces can include the use of special processing atmospheres. During gas quenching, these furnaces may operate at pressures from below atmospheric to over 100 psig.

Chapter 1 General

1-1 Scope.

1-1.1 This standard shall apply to ovens and furnaces operating above ambient temperatures to over 5000°F (2760°C) and at pressures normally below atmospheric to 10^{-8} torr (1.33×10^{-6} Pa).

1-1.2* Types of Furnaces. The user's requirements for vacuum processing shall determine the type of furnace walls, the size of the furnace, the special atmospheres required, or the reduction from normal atmosphere down to a special vacuum of 10^{-8} torr (1.33×10^{-6} Pa).

1-2 Purpose. Because the heat processing of materials can involve a serious fire and explosion hazard that can endanger the furnace and the building in which the process is located and possibly the lives of employees, adequate safeguards shall be provided as appropriate for the location, equipment, and operation of such furnaces.

1-3 Application.

1-3.1 The requirements of Chapters 1 through 5 shall apply to equipment described in subsequent chapters except as modified by those chapters.

1-3.2* This entire standard shall apply to new installations or alterations or extensions to existing equipment.

1-3.3 Section 1-5 and Chapter 11 shall apply to all operating furnaces.

1-3.4 No standard can guarantee the elimination of furnace fires and explosions. Technology in this area is under constant development, which is reflected in fuel, special processing atmospheres, flammable vapors, and quench systems, with regard to the type of equipment and the characteristics of the various fluids. Therefore, the designer is cautioned that the standard is not a design handbook. The standard does not eliminate the need for the engineer or competent engineering judgment. It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of furnace designs. In such cases, the designer shall be responsible for demonstrating and documenting the safety and validity of the design.

1-4* Approvals, Plans, and Specifications.

1-4.1 Before new equipment is installed or existing equipment is remodeled, complete plans, sequence of operations, and specifications shall be submitted for approval to the authority having jurisdiction.

1-4.1.1 Plans shall be drawn and shall show all essential details with regard to location, construction, ventilation, piping, and electrical safety equipment. A list of all combustion, control, and safety equipment giving manufacturer and type number shall be included.

1-4.1.2 Wiring diagrams and sequence of operations for all safety controls shall be provided. Ladder-type schematic diagrams are recommended.

1-4.2 Any deviation from this standard shall require special permission from the authority having jurisdiction.

1-4.3 Electrical.

1-4.3.1* All wiring shall be in accordance with NFPA 70, *National Electrical Code*®, NFPA 79, *Electrical Standard for Industrial Machinery*, and as described hereafter.

1-4.3.2 Wiring and equipment installed in hazardous (classified) locations shall comply with the applicable requirements of NFPA 70, *National Electrical Code*.

1-4.3.3* The installation of an oven in accordance with the requirements of this standard shall not in and of itself require a change to the classification of the oven location.

1-5 Operator and Maintenance Personnel Training.

1-5.1 All operating, maintenance, and appropriate supervisory personnel shall be thoroughly instructed and trained under the direction of a qualified person(s) and shall be required to demonstrate understanding of the equipment and its operation to ensure knowledge of and practice of safe operating procedures.

1-5.2 All operating, maintenance, and appropriate supervisory personnel shall receive regularly scheduled retraining and testing to maintain a high level of proficiency and effectiveness.

1-5.3 Personnel shall have access to operating instructions at all times.

1-5.4 Operator training shall include the following, where applicable:

(1) Combustion of fuel–air mixtures
(2) Explosion hazards
(3) Sources of ignition, including autoignition (e.g., by incandescent surfaces)
(4) Functions of control and safety devices
(5) Handling of special atmospheres
(6) Handling of low-oxygen atmospheres
(7) Handling and processing of hazardous materials
(8) Confined space entry procedures
(9) Vacuum technology
(10) Operating instructions *(see 1-5.5)*

1-5.5 Operating instructions shall be provided by the equipment manufacturer and shall include all of the following:

(1) Schematic piping and wiring diagrams
(2) Start-up procedures
(3) Shutdown procedures
(4) Emergency procedures, including those occasioned by loss of special atmospheres, electric power, inert gas, or other essential utilities
(5) Maintenance procedures

1-6 Equipment Maintenance. All equipment shall be maintained in accordance with the manufacturer's instructions.

1-7 Safety Labeling.

1-7.1 A suitable, clearly worded, and prominently displayed safety design data form or manufacturer's nameplate shall be provided that states the safe operating conditions for which the furnace system was designed, built, altered, or extended.

1-7.2 A warning label shall be provided by the manufacturer stating that the equipment shall be operated and maintained according to instructions. This label shall be permanently affixed to the furnace.

Chapter 2 Definitions

2-1 Definitions. The following definitions shall apply to NFPA 86, *Standard for Ovens and Furnaces*; NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere;* and NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*:

Afterburner. See *Incinerator, Fume.*

Air, Combustion. All the air introduced with fuel to supply heat in a furnace.

Air, Primary. All air supplied through the burner.

Air, Reaction. All the air that, when reacted with gas in an endothermic generator by the indirect addition of heat, becomes a special atmosphere gas.

Air, Secondary. All the combustion air that is intentionally allowed to enter the combustion chamber in excess of primary air.

Air Makeup Unit, Direct-Fired. A Class B fuel-fired heat utilization unit operating at approximately atmospheric pressure used to heat outside replacement air for the process or building.

Analyzer, Gas. A device that measures concentrations, directly or indirectly, of some or all components in a gas or mixture.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

Backfire Arrester. A flame arrester installed in fully premixed air—fuel gas distribution piping to terminate flame propagation therein, shut off fuel supply, and relieve pressure resulting from a backfire.

Bath, Molten Salt. See *Furnace, Molten Salt Bath.*

Burn-In. The procedure used in starting up a special atmosphere furnace to replace air within the heating chamber(s) and vestibule(s) with flammable special atmosphere.

Burn-Out. The procedure used in shutting down or idling a special atmosphere to replace flammable atmosphere within the heating chamber(s) and vestibule(s) with a nonflammable atmosphere.

Burner. A device or group of devices used for the introduction of fuel, air, oxygen, or oxygen-enriched air into a furnace at the required velocities, turbulence, and concentration to maintain ignition and combustion of fuel.

Burner, Atmospheric. A burner used in the low-pressure fuel gas or atmospheric system that requires secondary air for complete combustion.

Burner, Atomizing. A burner in which oil is divided into a fine spray by an atomizing agent, such as steam or air.

Burner, Blast. A burner delivering a combustible mixture under pressure, normally above 0.3 in. w.c. (75 kPa), to the combustion zone.

Burner, Combination Fuel Gas and Oil. A burner that can burn either fuel gas or oil, or both simultaneously.

Burner, Dual-Fuel. A burner designed to burn either fuel gas or oil, but not both simultaneously.

Burner, Line. A burner whose flame is a continuous "line."

Burner, Multiple-Port. A burner having two or more separate discharge openings or ports.

Burner, Nozzle Mixing. A burner in which the fuel and air are introduced separately to the point of ignition.

Burner, Premix. A burner in which the fuel and air are mixed prior to the point of ignition.

Burner, Pressure Atomizing. A burner in which oil under high pressure is forced through small orifices to emit liquid fuel in a finely divided state.

Burner, Radiant. A burner designed to transfer a significant part of the combustion heat in the form of radiation.

Burner, Radiant Tube. A burner designed to provide a long flame within a tube to ensure substantially uniform radiation from the tube surface.

Burner, Rotary Atomizing. A burner in which oil is atomized by applied centrifugal force, such as by a whirling cone or plate.

Burner, Self-Piloted. A burner in which the pilot fuel is issued from the same ports as the main flame or merges with the main flame to form a common flame envelope with a common flame base.

Burner System. One or more burners operated as a unit by a common safety shutoff valve(s).

Check, Safe-Start. A checking circuit incorporated in a safety control circuit that prevents light-off if the flame-sensing relay of the combustion safeguard is in the unsafe (flame-present) position due to component failure within the combustion safeguard or due to the presence of actual or simulated flame.

Cock, Supervising. A special approved cock incorporating in its design a means for positive interlocking with a main fuel safety shutoff valve so that, before the main fuel safety shutoff valve can be opened, all individual burner supervising cocks must be in the fully closed position.

Combustion Safety Circuitry. That portion of the oven control circuitry that contains the contacts for the required safety interlocks and the excess temperature limit controller(s). These contacts are arranged in series ahead of the safety shutoff valve(s) holding medium.

Controller, Continuous Vapor Concentration. A device that measures, indicates, and directly or indirectly controls the concentration of a flammable vapor-air mixture in percentage of the lower explosive limit (LEL).

Controller, Excess Temperature Limit. A device designed to cut off the source of heat if the operating temperature exceeds a predetermined temperature set point.

Controller, Programmable. A digital electronic system designed for use in an industrial environment that uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions to control, through digital or analog inputs and outputs, various types of machines or processes.

Controller, Temperature. A device that measures the temperature and automatically controls the input of heat into the furnace.

Cryogenic Fluid. A fluid produced or stored at very low temperatures. In the context of this standard, cryogenic fluid generally refers to gases made at low temperatures and stored at the user site in an insulated tank for use as an atmosphere or atmosphere constituent (e.g., nitrogen, argon, carbon dioxide, hydrogen, oxygen).

Damper, Cut-Away. A restricting airflow device that, when placed in the maximum closed position, allows a minimum amount of airflow past the restriction. Cut-away dampers normally are placed in the exhaust or fresh air intake ducts to ensure that the required minimum amount of exhaust or fresh air is handled by the ventilating fans.

Explosion-Resistant (Radiant Tube). The ability of a radiant tube or radiant tube heat recovery system to withstand the overpressure developed by the combustion of a stoichiometric ratio of approximately 10 volumes of combustion air to one volume of natural gas (or the stoichiometric ratio of other gaseous fuel). The radiant tube or the radiant tube heat recovery system may experience bulging and distortion but should not fail catastrophically.

Fire Check, Automatic. A flame arrester equipped with a check valve to shut off the fuel gas supply automatically if a backfire occurs.

Flame, Supervised. A flame whose presence or absence is detected by a flame sensor connected to a combustion safeguard.

Flame Arrester. A device installed in the small branch piping of a fully premixed air–fuel gas mixture to retard a flame front originating from a backfire.

Flame Propagation Rate. The speed at which a flame progresses through a combustible fuel–air mixture. This rate is a function of the temperature and the mixture conditions existing in the combustion space, burner, or piping under consideration.

Flame Rod. A detector that employs an electrically insulated rod of temperature-resistant material that extends into the flame being supervised, with a voltage impressed between the rod and a ground connected to the nozzle or burner. The resulting electrical current, which passes through the flame, is rectified, and this rectified current is detected and amplified by the combustion safeguard.

Fluid, Pump. The operating fluid used in diffusion pumps or in liquid-sealed mechanical pumps (sometimes called *working medium, working fluid,* or *pump oil*).

Fuel Gas. Gas used for heating, such as natural gas, manufactured gas, undiluted liquefied petroleum gas (vapor phase only), liquefied petroleum gas–air mixtures, or mixtures of these gases.

Fuel Gas System, High Pressure. A system using the kinetic energy of a jet of 1 psig (7 kPa) or higher gas pressure to entrain from the atmosphere all, or nearly all, the air required for combustion.

Fuel Gas System, Low Pressure or Atmospheric. A system using the kinetic energy of a jet of less than 1 psig (7 kPa) gas pressure to entrain from the atmosphere a portion of the air required for combustion.

Fuel Oil. Grades 2, 4, 5, or 6 fuel oils as defined in ASTM D 396, *Standard Specifications for Fuel Oils*.

Furnace, Atmosphere. A furnace built to allow heat processing of materials in a special processing atmosphere.

Furnace, Batch. A furnace into which the work charge is introduced all at once.

Furnace, Class A. An oven or furnace that has heat utilization equipment operating at approximately atmospheric pressure wherein there is a potential explosion or fire hazard that could be occasioned by the presence of flammable volatiles or combustible materials processed or heated in the furnace. Flammable volatiles or combustible materials can include, but are not limited to, any of the following: (1) paints, powders, inks, and adhesives from finishing processes, such as dipped, coated, sprayed, and impregnated materials; (2) substrate material; (3) wood, paper, and plastic pallets, spacers, or packaging materials; or (4) polymerization or other molecular rearrangements. In addition, potentially flammable materials, such as quench oil, water-borne finishes, cooling oil, or cooking oils, that present a hazard are ventilated according to Class A standards.

Furnace, Class B. An oven or furnace that has heat utilization equipment operating at approximately atmospheric pressure wherein there are no flammable volatiles or combustible materials being heated.

Furnace, Class C. An oven or furnace that has a potential hazard due to a flammable or other special atmosphere being used for treatment of material in process. This type of furnace can use any type of heating system and includes a special atmosphere supply system(s). Also included in the Class C classification are integral quench furnaces and molten salt bath furnaces.

Furnace, Class D. An oven or furnace that operates at temperatures above ambient to over 5000°F (2760°C) and at pressures from vacuum to several atmospheres during heating using any type of heating system. These furnaces can include the use of special processing atmospheres. During inert gas quenching, these furnaces may operate at pressures from below atmospheric to over 100 psig.

Furnace, Continuous. A furnace into which the work charge is more or less continuously introduced.

Furnace, Molten Salt Bath. A furnace that employs salts heated to a molten state. These do not include aqueous alkaline baths, hot brine, or other systems utilizing salts in solution.

Furnace, Plasma Arc. A furnace that employs the passage of an electric current between either a pair of electrodes or between electrodes and the work, and ionizing a gas (such as argon) and transferring energy in the form of heat.

Gas, Ballast. Atmospheric air or a dry gas that is admitted into the compression chamber of rotary mechanical pumps to prevent condensation of vapors in the pump oil by maintaining the partial pressure of the condensable vapors below the saturation value (also called *vented exhaust*).

Gas, Inert. See *Special Atmosphere, Inert (Purge Gas).*

Gas, Reaction. A gas that, when reacted with air in an endothermic generator by the addition of heat, becomes a special atmosphere gas.

Gas Quenching. The introduction of a gas, usually nitrogen or argon (in certain situations helium or hydrogen may be used), into the furnace to a specific pressure [usually between –2.5 psig to 15 psig (0.85 bar to 2.05 bar)] for the purpose of cooling the work. The gas is recirculated over the work and through a heat exchanger by means of a fan or blower.

Gas Quenching, High Pressure. Gas-cooling at pressures greater than 15 psig.

Gauge, Vacuum. A device that indicates the absolute gas pressure in a vacuum system.

Guarded. Covered, shielded, fenced, enclosed, or otherwise protected by such means as suitable covers or casings, barriers, rails or screens, mats, or platforms.

Heater, Dielectric. A heater similar to an induction heater, but using frequencies that generally are higher (3 MHz or more) than those used in induction heating. This type of heater is useful for heating materials that commonly are thought to be nonconductive. Examples of uses include heating plastic preforms before molding, curing glue in plywood, drying rayon cakes, and other similar applications.

Heater, Direct-Fired External. A heating system in which the burners are in a combustion chamber effectively separated from the work chamber and arranged so that products of combustion from the burners are discharged into the work chamber by a circulating fan or blower.

Heater, Direct-Fired Internal. A heating system in which the burners are located within the work chamber.

Heating System, Direct-Fired.* A heating system in which the products of combustion enter the work chamber.

Heating System, Indirect-Fired. A heating system in which the products of combustion do not enter the work chamber.

Heating System, Indirect-Fired Internal. A heating system of gastight radiators containing burners not in contact with the oven atmosphere. Radiators might be designed to withstand explosion pressures from ignition of air–fuel mixtures in the radiators.

Heating System, Induction. A heating system by means of which a current-carrying conductor induces the transfer of electrical energy to the work by eddy currents. *(See NFPA 70, National Electrical Code, Article 665.)*

Heating System, Radiant Tube. A heating system with tubular elements open at one or both ends. Each tube has an inlet burner arrangement where combustion is initiated, a suitable length where combustion occurs, and an outlet for the combustion products formed.

Heating System, Resistance. A system in which heat is produced by current flow through a resistive conductor. Resistance heaters can be of the open type, with bare heating conductors, or insulated sheath type, with conductors covered by a protecting sheath that can be filled with electrical insulating material.

Heating System, Tubular. A form of radiant heater in which resistive conductors are enclosed in glass, quartz, or ceramic envelopes that can contain a special gas atmosphere.

Implosion. The rapid inward collapsing of the walls of a vacuum component or device as the result of failure of the walls to sustain the atmospheric pressure. This can be followed by an outward scattering of pieces of the wall if the wall material is not ductile, thus causing possible danger to nearby equipment and personnel.

Incinerator, Fume. Any separate or independent combustion equipment or device that entrains the process exhaust for the purpose of direct thermal or catalytic destruction, which can include heat recovery.

Insulation, Vacuum-Type. A highly reflective double-wall structure with high vacuum between the walls; used as insulation in cryogenic systems for the reduction of heat transfer.

Interlock, Proved Low-Fire Start. A burner start interlock in which a control sequence ensures that a high-low or modulated burner is in the low-fire position before the burner can be ignited.

Interlock, Safety. A device required to ensure safe start-up and safe operation and to cause safe equipment shutdown.

Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Limiting Oxidant Concentration (LOC). The concentration of oxidant below which a deflagration cannot occur. Materials other than oxygen can act as oxidants.

Listed.* Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

LOC. See *Limiting Oxidant Concentration.*

Lower Explosive Limit (LEL). See *Range, Explosive.*

Mixer, Air Jet. A mixer using the kinetic energy of a stream of air issuing from an orifice to entrain the fuel gas required for combustion. In some cases, this type of mixer can be designed to entrain some of the air for combustion as well as the fuel gas.

Mixer, Air–Fuel Gas. A system that combines air and fuel gas in the proper proportion for combustion.

Mixer, Gas Jet [Atmospheric Inspirator (Venturi) Mixer]. A mixer using the kinetic energy of a jet of fuel gas issuing from an orifice to entrain all or part of the air required for combustion.

Mixer, Proportional. A mixer comprised of an inspirator that, when supplied with air, draws all the fuel gas necessary for combustion into the airstream, and a governor, zero regulator, or ratio valve that reduces incoming fuel gas pressure to approximately atmospheric.

Mixing Blower. A motor-driven blower to supply air–fuel gas mixtures for combustion through one or more fuel burners or nozzles on a single-zone industrial heating appliance or on each control zone of a multizone installation. Mixing machines operated at 10 in. w.c. (2.49 kPa) or less static pressure are considered mixing blowers.

Mixing Machine. A mixer using mechanical means to mix fuel and air and to compress the resultant mixture to a pressure suitable for delivery to its point of use. Mixers in this group utilize either a centrifugal fan or some other type of mechanical compressor with a proportioning device on its intake through which fuel and air are drawn by the fan or compressor suction.

Muffles. Enclosures within a furnace to separate the source of heat from the work and from any special atmosphere that might be required for the process.

Operator. An individual trained and responsible for the start-up, operation, shutdown, and emergency handling of the furnace and associated equipment.

Outgassing. The release of adsorbed or occluded gases or water vapor, usually by heating, such as from a vacuum tube or other vacuum system.

Oven. See *Furnace* definitions.

Oven, Low-Oxygen. An oven that utilizes a low-oxygen atmosphere to evaporate solvent to facilitate solvent recovery. These ovens normally operate at high solvent levels and can operate safely in this manner by limiting the oxygen concentration within the oven enclosure.

Pilot. A flame that is used to light the main burner.

Pilot, Burn-off. A pilot that ignites the flame curtain or special processing atmosphere discharging from the furnace or generator.

Pilot, Continuous. A pilot that burns throughout the entire period that the heating equipment is in service, whether or not the main burner is firing.

Pilot, Expanding. A pilot that burns at a set turndown throughout the entire period that the heating equipment is in service, but burns without turndown during light-off of the main burner.

Pilot, Intermittent. A pilot that burns during light-off and while the main burner is firing.

Pilot, Interrupted. A pilot that is ignited and burns during light-off and is automatically shut off at the end of the trial-for-ignition period of the main burner(s).

Pilot, Proved. A pilot flame supervised by a combustion safeguard that senses the presence of the pilot flame.

Pilot Flame Establishing Period. The interval of time during light-off that a safety control circuit allows the pilot fuel safety shutoff valve to remain open before the combustion safeguard proves the presence of the pilot flame.

Pressure, Partial. The pressure that is exerted by one component of a mixture of gases if it is present alone in a container.

Pressure, Ultimate. The limiting pressure approached in the vacuum system after sufficient pumping time to establish that further reductions in pressure would be negligible (sometimes called the *ultimate vacuum*).

Pump, Diffusion. A vacuum pump in which a stream of heavy molecules, such as those of mercury or oil vapor, carries gas molecules out of the volume being evacuated.

Pump, Gas Ballast. A mechanical pump (usually of the rotary type) that uses oil to seal the clearances between the stationary and rotating compression members. The pump is equipped with an inlet valve through which a suitable quantity of atmospheric air or "dry" gas (ballast gas) can be admitted into the compression chamber to prevent condensation of vapors in the pump oil by maintaining the partial pressure of the condensable vapors in the oil below the saturation value (sometimes called a *vented-exhaust mechanical pump*).

Pump, Holding. A backing (fore) pump used to hold a diffusion pump at efficient operating conditions while a roughing pump reduces the system pressure to a point at which a valve between the diffusion pump and the system can be opened without stopping the flow of vapor from the nozzles.

Pump, Rotary Blower. A pump without a discharge valve that moves gas by the propelling action of one or more rapidly rotating members provided with lobes, blades, or vanes, such as a roots blower. It is sometimes called a *mechanical booster pump* where used in series with a mechanical backing (fore) pump.

Pump, Roughing.* The pump used to reduce the system pressure to the level at which a diffusion or other vacuum pump can operate.

Pump, Vacuum. A compressor for exhausting air and noncondensable gases from a space that is to be maintained at subatmospheric pressure.

Pump-Down Factor. The product of the time to pump down to a given pressure and the displacement (for a service factor of 1) divided by the volume of the system ($F = t\,D/V$).

Purge. The replacement of a flammable, indeterminate, or high-oxygen-bearing atmosphere with another gas that, when complete, results in a nonflammable final state.

Range, Explosive.* The range of concentration of a flammable gas in air within which a flame can be propagated. The lowest flammable concentration is the lower explosive limit (LEL). The highest flammable concentration is the upper explosive limit (UEL).

Regulator, Pressure. A device that maintains a constant outlet pressure under varying flow.

Roughing Line. A line running from a mechanical pump to a vacuum chamber through which preliminary pumping is conducted to a vacuum range at which a diffusion pump or other high vacuum pump can operate.

Safeguard, Combustion. A safety control directly responsive to flame properties; it senses the presence or absence of flame and de-energizes the fuel safety valve in the event of flame failure within 4 seconds of the loss of flame signal.

Safety Device. An instrument, control, or other equipment that acts, or initiates action, to cause the furnace to revert to a safe condition in the event of equipment failure or other hazardous event. Safety devices are redundant controls, supplementing controls utilized in the normal operation of a furnace system. Safety devices act automatically, either alone or in conjunction with operating controls, when conditions stray outside of design operating ranges and endanger equipment or personnel.

Separator, Oil. An oil reservoir with baffles used to minimize the discharge of oil mist from the exhaust of a rotary mechanical vacuum pump.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Special Atmosphere. Prepared gas or gas mixtures that are introduced into the work chamber of a furnace to replace air, generally to protect or intentionally change the surface of the material undergoing heat processing (heat treatment).

Special Atmosphere, Carrier Gas. Any gas or liquid component of the special atmosphere that represents a sufficient portion of the special atmosphere gas volume in the furnace so that, if the flow of this component gas or liquid ceases, the total flow of the special atmosphere in the furnace is not sufficient to maintain a positive pressure in that furnace.

Special Atmosphere, Flammable. Gases that are known to be flammable and predictably ignitible where mixed with air.

Special Atmosphere, Generated. Atmospheres created in an ammonia dissociator, exothermic generator, or endothermic generator by dissociation or chemical reaction of *reaction air* and *reaction gas.*

Special Atmosphere, Indeterminate. Atmospheres that contain components that, in their pure state, are flammable but that, in the mixtures used (diluted with nonflammable gases), are not reliably and predictably flammable.

Special Atmosphere, Inert (Purge Gas). Nonflammable gases that contain less than 1 percent oxygen.

Special Atmosphere, Nonflammable. Gases that are known to be nonflammable at any temperature.

Special Atmosphere, Synthetic. Those atmospheres such as anhydrous ammonia, hydrogen, nitrogen, or inert gases obtained from compressed gas cylinders or bulk storage tanks and those derived by chemical dissociation or mixing of hydrocarbon fluids. Synthetic atmospheres include mixtures of synthetic and generated atmospheres.

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Switch, Atomizing Medium Pressure. A pressure-activated device arranged to effect a safety shutdown or to prevent the burner system from being actuated in the event of inadequate atomizing medium pressure.

Switch, Combustion Air Pressure. A pressure-activated device arranged to effect a safety shutdown or to prevent the burner system from being actuated in the event the combustion air supplied to the burner or burners falls below that recommended by the burner manufacturer.

Switch, Differential Flow. A switch that is activated by the flow of a gaseous or liquid fluid. This flow is detected by measuring pressure at two different points to produce a pressure differential across the sensor.

Switch, Flow. A switch that is activated by the flow of a fluid in a duct or piping system.

Switch, High Fuel Pressure. A pressure-activated device arranged to effect a safety shutdown of the burner system in the event of abnormally high fuel pressure.

Switch, Limit. A switching device that actuates when an operating limit has been reached.

Switch, Low Fuel Pressure. A pressure-activated device arranged to effect a safety shutdown of the burner system in the event of abnormally low fuel pressure.

Switch, Rotational. A device that usually is driven directly by the fan wheel or fan motor shaft. When the speed of the fan shaft or drive motor reaches a certain predetermined rate to provide a safe minimum airflow, a switch contact closes.

Tank, Integral Liquid or Salt Media Quench Type. A tank connected to the furnace so that the work is under a protective atmosphere from the time it leaves the heating zone until it enters the tank containing a combustible, noncombustible, or salt quench medium.

Tank, Open Liquid or Salt Media Quench Type. A tank in which work from the furnace is exposed to air before and upon entering the tank containing a combustible, noncombustible, or salt quench medium.

Temperature, Ignition. The lowest temperature at which a gas–air mixture can ignite and continue to burn. This also is referred to as the autoignition temperature.

Time, Evacuation. The time required to pump a given system from atmospheric pressure to a specified pressure (also known as *pump-down time* or *time of exhaust*).

Time, Roughing. The time required to pump a given system from atmospheric pressure to a pressure at which a diffusion pump or other high vacuum pump can operate.

Trial-for-Ignition Period (Flame-Establishing Period). The interval of time during light-off that a safety control circuit allows the fuel safety shutoff valve to remain open before the combustion safeguard is required to supervise the flame.

Turndown, Burner. The ratio of maximum to minimum burner fuel-input rates.

Vacuum. A space in which the pressure is far below atmospheric pressure so that the remaining gases do not affect processes being carried out in the space.

Vacuum, High. A vacuum with a pressure between 1×10^{-3} torr and 1×10^{-5} torr (millimeters of mercury).

Vacuum, Low. A vacuum with a pressure between 760 torr and 1×10^{-3} torr (millimeters of mercury).

Vacuum System. A chamber or chambers having walls capable of withstanding atmospheric pressure and having an opening through which the gas can be removed through a pipe or manifold to a pumping system. A complete vacuum system contains all pumps, gauges, valves, and other components necessary to carry out a particular process.

Valve, Air Inlet. A valve used for letting atmospheric air into a vacuum system. The valve also is called a vacuum breaker.

Valve, Safety Shutoff. A normally closed (closed when de-energized) valve installed in the piping that closes automatically to shut off the fuel, atmosphere gas, or oxygen in the event of abnormal conditions or during shutdown. The valve can be opened either manually or automatically, but only after the solenoid coil or other holding mechanism is energized.

Ventilated. A system provided with a method to allow circulation of air sufficient to remove an excess of heat, fumes, or vapors.

Ventilation, Proven. A sufficient supply of fresh air and proper exhaust to outdoors with a sufficiently vigorous and properly distributed air circulation to ensure that the flammable vapor concentration in all parts of the furnace or furnace enclosure is safely below the lower explosive limit at all times.

Chapter 3 Location and Construction

3-1 Location.

3-1.1 General.

3-1.1.1 Furnaces and related equipment shall be located so as to protect personnel and buildings from fire or explosion hazards. Hazards to be considered include molten metal or other molten material spillage, quench tanks, hydraulic oil ignition, overheating of material in the furnace, and escape of fuel, processing atmospheres, or flue gases.

3-1.1.2 Furnaces shall be located so as to protect them from damage by external heat, vibration, and mechanical hazards.

3-1.1.3 Furnaces shall be located so as to make maximum use of natural ventilation, to minimize restrictions to adequate explosion relief, and to provide sufficient air supply for personnel.

3-1.1.4* Where furnaces are located in basements or enclosed areas, sufficient ventilation shall be supplied so as to provide required combustion air and to prevent the hazardous accumulation of vapors.

3-1.1.5 Furnaces designed for use with special atmospheres or fuel gas with a specific gravity greater than air shall be located at or above grade and shall be located so as to prevent the escape of the special atmosphere or fuel gas from accumulating in basements, pits, or other areas below the furnace.

3-1.2 Structural Members of the Building.

3-1.2.1 Furnaces shall be located and erected so that the building structural members are not affected adversely by the maximum anticipated temperatures *(see 3-1.4)* or by the additional loading caused by the furnace.

3-1.2.2 Structural building members shall not pass through or be enclosed within a furnace.

3-1.3 Location in Regard to Stock, Processes, and Personnel.

3-1.3.1 Furnaces shall be located so as to minimize exposure to power equipment, process equipment, and sprinkler risers. Unrelated stock and combustible materials shall be maintained at a fire-safe distance but not less than 2.5 ft (0.76 m) from a furnace, a furnace heater, or ductwork.

3-1.3.2 Furnaces shall be located so as to minimize exposure of people to the possibility of injury from fire, explosion, asphyxiation, and hazardous materials and shall not obstruct personnel travel to exitways.

3-1.3.3* Furnaces shall be designed or located so as to prevent an ignition source to flammable coating dip tanks, spray booths, storage and mixing rooms for flammable liquids, or exposure to flammable vapor or combustible dusts.

Exception: This requirement shall not apply to integral quench systems.

3-1.3.4 Equipment shall be protected from corrosive external processes and environments, including fumes or materials from adjacent processes or equipment that produce corrosive conditions when introduced into the furnace environment.

3-1.4 Floors and Clearances.

3-1.4.1 Furnaces shall be located with adequate space above and on all sides to allow inspection and maintenance. Provisions also shall be included for the installation of automatic sprinklers and the proper functioning of explosion vents, if applicable.

3-1.4.2* Furnaces shall be constructed and located to keep temperatures at combustible floors, ceilings, and walls below 160°F (71°C).

3-1.4.3 Where electrical wiring is present in the channels of certain types of floors, the wiring shall be installed in accordance with NFPA 70, *National Electrical Code*, Article 356.

3-1.4.4 Floors in the area of mechanical pumps, oil burners, or other equipment using oil shall be provided with a noncombustible, nonporous surface to prevent floors from becoming soaked with oil.

3-2 Furnace Design.

3-2.1 Furnaces and related equipment shall be designed to minimize the fire hazard inherent in equipment operating at elevated temperatures.

3-2.2 Furnace components exposed simultaneously to elevated temperatures and air (oxygen) shall be constructed of noncombustible material.

3-2.3 Furnace structural supports and material-handling equipment shall be designed with adequate factors of safety at the maximum operating conditions, including temperature. Furnaces shall withstand the strains imposed by expansion and contraction, as well as static and dynamic mechanical load.

3-2.4 Heating devices and heating elements of all types shall be constructed or located so as to resist mechanical damage from falling work, material handling, or other mechanical hazards.

3-2.5 Furnace and related equipment shall be designed and located to allow access for required inspection and maintenance.

3-2.5.1 Ladders, walkways, and access facilities, where provided, shall be designed in accordance with 29 *CFR* 1910.24 through 29 *CFR* 1910.29 and ANSI A14.3, *Safety Requirements for Fixed Ladders.*

3-2.5.2 Means shall be provided to allow for safe entry by maintenance and other personnel. *(See also A-11-1.)*

3-2.6 Radiation shields, refractory material, and insulation shall be retained or supported so they do not fall out of place under designed use and with proper maintenance.

3-2.7 External parts of furnaces that operate at temperatures in excess of 160°F (71°C) shall be guarded by location, guard rails, shields, or insulation to prevent accidental contact with personnel. Bursting discs or panels, mixer openings, or other parts of the furnace from which flame or hot gases could be discharged shall be located or guarded to prevent injury to personnel.

Exception: Where impractical to provide adequate shields or guards, warning signs or permanent floor markings shall be provided to be visible to personnel entering the area.

3-2.8 Properly located observation ports shall be provided so the operator can observe the lighting and operation of individual burners. Observation ports shall be protected properly from radiant heat and physical damage.

Exception: Where observation ports are not practical, other means of visually verifying the lighting and operation of individual burners shall be provided.

3-2.9 Closed cooling systems shall have a means of relief to protect all portions of the system, if the system pressure can exceed the design pressure. Flow switches shall be provided with audible and visual alarms.

3-2.10 Open cooling systems utilizing unrestricted sight drains readily observable by the operator shall not require flow switches.

3-2.11 Where a cooling system is critical to continued safe operation, the cooling system shall continue to operate after a safety shutdown or power failure.

3-2.12* Furnaces shall be designed to minimize fire hazards due to the presence of combustible products or residue in the furnace.

3-2.13 Furnace hydraulic systems shall utilize fire-resistant fluids.

Exception: Other hydraulic fluids shall be permitted to be used if failure of hydraulic system components cannot result in a fire hazard, subject to approval by the authority having jurisdiction.

3-2.14 The metal frames of furnaces shall be electrically grounded.

3-2.15* Water-cooled components, such as vacuum vessels, shall be designed with minimum wall thicknesses in accordance with corrosion tables and vessel standards.

3-2.16 Where the vacuum chamber operates at a positive internal pressure of greater than 15 psig (103.4 kPa), the vacuum chamber shall be designed and constructed in accordance with ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1. The additional pressure due to water in the cooling jacket shall be considered in calculating maximum pressure differentials.

3-3 Explosion Relief.

3-3.1* Fuel-fired furnaces and furnaces that contain flammable liquids, gases, or combustible dusts shall be equipped with unobstructed explosion relief for freely relieving internal explosion pressures.

Exception: Explosion relief shall not be required on furnaces with shell construction having $^3/_{16}$-in. (4.8-mm) or heavier steel plate shells reinforced with structural steel beams and buckstays that support and retain refractory insulating materials required for temperature endurance, which make them unsuitable for the installation of explosion relief.

3-3.2 Explosion relief shall be designed as a ratio of relief area to furnace volume. The minimum design shall be at least 1 ft^2 (0.093 m^2) of relief area for each 15 ft^3 (0.424 m^3) of furnace volume. Hinged panels, openings, or access doors equipped with approved explosion-relief hardware shall be permitted to be included in this ratio of 1:15.

3-3.3 Explosion-relief vents shall be arranged so that, when open, the full vent opening provides an effective relief area. The operation of vents to their full capacity shall not be obstructed. Warning signs shall be posted on the vents.

3-3.4* Explosion-relief vent(s) shall be located as close as practicable to each known source of ignition to minimize damage.

3-3.5 Explosion-relief vents shall be located or retained so that personnel are not exposed to injury by operation of the vents.

3-3.6* Where explosion relief is required, explosion-relief vents shall activate at a surge pressure that does not exceed the design pressure of the oven enclosure.

3-3.7* Explosion-relief vents for a long furnace shall be reasonably distributed throughout the entire furnace length. However, the maximum distance between explosion-relief vents shall not exceed five times the oven's smallest inside dimension (width or height).

3-4* Ventilation and Exhaust System.

3-4.1 Building Makeup Air. A sufficient quantity of makeup air shall be admitted to oven rooms and buildings to provide the air volume required for oven safety ventilation and adequate combustion air.

3-4.2 Fans and Motors.

3-4.2.1 Electric motors that drive exhaust or recirculating fans shall not be located inside the oven or ductwork.

Exception: Electric motors shall be permitted to be used in vacuum furnaces.

3-4.2.2 Oven recirculation and exhaust fans shall be designed for the maximum oven temperature and for material and vapors being released during the heating process.

3-4.3 Ductwork.

3-4.3.1 Ventilating and exhaust systems, where applicable, shall be installed in accordance with Chapters 1, 2, and 3 of NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids,* unless otherwise noted.

3-4.3.2 Rectangular and square ducts shall be permitted.

3-4.3.3 Wherever furnace ducts or stacks pass through combustible walls, floors, or roofs, noncombustible insulation or clearance, or both, shall be provided to prevent combustible surface temperatures from exceeding 160°F (71°C).

3-4.3.4* Where ducts pass through noncombustible walls, floors, or partitions, the space around the duct shall be sealed with noncombustible material to maintain the fire rating of the barrier.

3-4.3.5 Ducts shall be constructed entirely of sheet steel or other noncombustible material capable of meeting the intended installation and conditions of service. The installation shall be of adequate strength and rigidity and shall be protected where subject to physical damage.

3-4.3.6 Ducts handling fumes that leave a combustible deposit shall be provided with clean-out doors.

3-4.3.7 No portions of the building shall be used as an integral part of the duct.

3-4.3.8* All ducts shall be made tight throughout and shall have no openings other than those required for the operation and maintenance of the system.

3-4.3.9 All ducts shall be thoroughly braced where required and substantially supported by metal hangers or brackets.

3-4.3.10 Ducts handling flammable vapors shall be designed to minimize the condensation of the vapors out of the exhaust airstream onto the surface of the ducts.

3-4.3.11 Ducts handling combustible solids shall be designed to minimize the accumulation of solids within the ducts.

3-4.3.12 Hand holes for damper, sprinkler, or fusible link inspection or resetting and for purposes of residue clean-out shall be equipped with tight-fitting doors or covers.

3-4.3.13 Exposed hot fan casings and hot ducts [temperature exceeding 160°F (71°C)] shall be guarded by location, guard rails, shields, or insulation to prevent injury to personnel.

3-4.3.14 Exhaust ducts shall not discharge near openings or other air intakes where effluents can re-enter the building.

3-4.3.15 A suitable collecting and venting system for radiant tube heating systems shall be provided. *(See Section 4-5.)*

3-4.4 Pump Vents.

3-4.4.1 Mechanical vacuum pumps with capacity larger than 15 ft^3/min (7×10^{-3} m^3/sec) shall be vented to a safe location in accordance with all applicable codes and air pollution control regulations.

3-4.4.2 An oil drip leg in accordance with the vacuum pump manufacturer's recommendation shall be designed into the vent piping system.

3-4.4.3 Vent piping shall be free from gas or oil leaks and shall be of noncombustible pipe construction.

3-4.4.4 An oil mist separator shall be provided where the discharge vapor accumulations create a hazard.

3-5 Mountings and Auxiliary Equipment.

3-5.1 Pipes, valves, and manifolds shall be mounted so as to provide protection against damage by heat, vibration, and mechanical hazard.

3-5.2 Furnace systems shall have provisions to prevent injury to personnel during maintenance or inspection. Such equipment shall be permitted to be motion stops, lockout devices, or other safety mechanisms.

3-5.3 To the extent practical, instrumentation and control equipment shall be brought to a common location and mounted for ease of observation, adjustment, and maintenance. Protection from physical and temperature damage and ambient hazards shall be provided.

3-5.4 Auxiliary equipment such as conveyors, racks, shelves, baskets, and hangers shall be noncombustible and designed to facilitate cleaning.

3-6 Pumping Systems.

3-6.1* For the purpose of Section 3-6 the term pumping systems shall include pumps; valves and associated piping and wiring; related protective equipment; and measuring and control instrumentation that produce and control the level of vacuum in a vacuum furnace. *(See Appendix B for general pump information.)*

3-6.2 Mechanical pumps utilizing hydrocarbon oils shall not be used for pumping gases with oxygen contents greater than 25 percent by volume.

3-6.3* Diffusion pumps and other pumps employing a heating source shall include thermostats or other automatic temperature-controlling devices.

3-6.4 A fluid level gauge shall be installed on those diffusion pumps with a pump fluid capacity over 1 qt (0.95 L).

3-6.5 Where petroleum or other combustible fluids are used, the pumping system shall be designed to minimize the possibility of fluid release that might result in a fire or explosion.

3-6.6 Sufficient cooling shall be provided for diffusion pumps to prevent excess vapors from backstreaming into furnace chambers and for mechanical pumps to prevent overheating of the pump fluids.

3-7 Vacuum Gauges and Controls.

3-7.1* Vacuum gauges and vacuum controls shall be selected for a particular system with consideration to vacuum level, sensitivity, and expected contamination.

3-7.2 Vacuum gauges shall be installed so levels of vacuum can be ascertained in the furnace chamber and between vacuum pumps of multipump systems.

3-7.3 Vacuum gauge controls that operate in conjunction with sequential controls shall be interlocked to prevent damage to the furnace components or work load.

3-7.4 Hot wire filament gauges shall not be used at pressures above 1×10^{-1} torr (13.3 Pa) in the presence of explosive vapors or combustible atmospheres.

3-8 Vacuum Piping Systems.

3-8.1 Vacuum pipe lines, valves, and manifolds shall be designed to withstand differential pressures, shall have sufficient conductance for the application, and shall have a maximum leak rate as required by the process but not greater than the leak rate specified by the furnace manufacturer.

3-8.2 Isolation vacuum valves shall be installed between the mechanical fore pumps and the remaining system, including the furnace chamber. These valves, if powered, shall automatically close when there is a loss of power to the fore pump or when the control switch for the fore pump is in the OFF position.

3-8.3 Where applicable, a bypass shall be provided between the furnace and roughing and the fore pump so that the chamber can be rough-pumped while the diffusion pump remains isolated.

3-8.4 Inlet gas quenching valves shall be designed to operate at applicable pressures on the gas side and on the vacuum side.

3-8.5 Where pressurized backfilling is employed, a pressure-relief valve shall be provided on the furnace. It shall be located on the chamber side of all vacuum valves and shall be set for a safe positive pressure limit consistent with the furnace chamber design criteria. *(See Section 5-20.)*

3-9 Water-Cooling Systems.

3-9.1 For the purposes of Section 3-9, the term *water-cooling system* of a vacuum furnace shall include the apparatus, equipment, and method used to cool vacuum chamber walls, electrical terminals, seals, work load, and, where applicable, the interior of the furnace.

3-9.2* Cold-wall vacuum furnaces shall be specifically designed to maintain the vacuum furnace vessel at proper temperatures. The furnace vessel walls shall be maintained at safe temperatures when the furnace operates at maximum temperatures.

3-9.3* Interlocks shall be provided on closed cooling systems to prevent heating system operation without proper flow of the cooling water at the return.

3-9.4 Provision shall be made to cool the terminals if heat from the electric power terminals can damage seals during processing cycles.

3-10* Gas Quenching Systems. See also 5-20.3.

3-10.1 Internal Heat Exchanger. Internal heat exchangers installed in the furnace chamber for the purpose of extracting heat from a recirculating cooling gas shall be protected from excessive pressure, heat damage, and mechanical damage while the furnace is being loaded or unloaded.

3-10.1.1 Heat exchangers, components, and connections shall be free from water and air leaks.

3-10.1.2 Heat exchangers shall be mounted to prevent vibration or thermal damage that could cause a rupture during processing cycles.

3-10.1.3 Heat exchanger components shall have sufficient strength to resist permanent deformation while exposed to the simultaneous maximum pressure of the coolant source and the maximum vacuum or pressure attained in the furnace.

3-10.2 External Heat Exchangers. External heat exchangers used for the purpose of extracting heat from a recirculating cooling gas shall be enclosed in a vacuumtight chamber that has a leak rate not exceeding the leak rate specified by the manufacturer for the furnace chamber.

3-10.2.1 Heat exchangers, components, and connections shall be free from water and air leaks.

3-10.2.2 Heat exchangers shall be mounted to prevent vibration or thermal damage that could cause a rupture during processing cycles.

3-10.2.3 Heat exchanger components shall have sufficient strength to resist permanent deformation while exposed to the simultaneous maximum pressure of the coolant source and the maximum vacuum or pressure attained in the furnace.

3-10.3 Fans and Motors for Gas Quenching Systems.

3-10.3.1 Fans shall not be exposed to any temperature in excess of their design temperature rating.

3-10.3.2 Electric fan motors shall be interlocked to prevent operation below a chamber pressure of 7 psi (48 kPa) absolute to prevent motor failure.

3-10.3.3 Where motor windings are exposed to argon gas or other ionizing gases, the voltage on the motor shall be limited to 260 volts maximum.

3-10.4 Quenching Gas. The recirculating gas shall be one that is not harmful to the heating elements, furnace heat shields or insulation, or work when introduced at the quenching temperature.

3-11 Heating Elements and Insulation.

3-11.1 Material for heating elements shall have a vapor pressure lower than the lowest pressure at the manufacturer's specified maximum temperature.

3-11.2 Internal electrical insulation material shall remain nonconductive through the full range of vacuum and temperature limits specified by the manufacturer.

3-12 Heat Baffles and Reflectors.

3-12.1 Baffles, reflectors, and hangers shall be designed to minimize warpage due to expansion and contraction.

3-12.2 Baffles, reflectors, and hangers shall be of heat-resistant material that minimizes sag, rupture, or cracking under normal operating limits specified by the manufacturer.

3-12.3 Baffles and reflectors shall be accessible and removable for the purpose of cleaning and repairing.

Chapter 4 Furnace Heating Systems

4-1 General.

4-1.1 For the purpose of this chapter, the term *furnace heating system* shall include the heating source, the associated piping and wiring used to heat the furnace, and the work therein as well as the auxiliary quenches, atmosphere generator, and other components.

4-1.2 All components of the furnace heating system and control cabinet shall be grounded.

4-2 Fuel Gas–Fired Units.

4-2.1 Scope.

4-2.1.1* Section 4-2 shall apply to furnace heating systems fired with commercially distributed fuel gases such as natural gas, mixed gas, manufactured gas, liquefied petroleum gas (LP-Gas) in the vapor phase, and LP-Gas/air systems. Section 4-2 also shall apply to the gas-burning portions of dual-fuel or combination burners.

4-2.1.2 Burners, along with associated mixing, valving, and safety controls and other auxiliary components, shall be properly selected for the intended application, suitable for the type and pressure of the fuel gases to be used, and suitable for the temperatures to which they are subjected.

4-2.2* Combustion Air.

4-2.2.1 The fuel-burning system design shall provide for an adequate supply of clean combustion air for proper burner operation.

4-2.2.2 Precautions shall be taken to prevent insufficiently diluted products of combustion from short-circuiting back into the combustion air. This requirement shall not prevent the use of properly designed flue gas recirculation systems.

4-2.2.3 Where primary or secondary combustion air is provided mechanically, combustion airflow or pressure shall be proven and interlocked with the safety shutoff valves so that fuel gas cannot be admitted prior to establishment of combustion air and so that the gas is shut off in the event of combustion air failure.

4-2.2.4 In the case of an exothermic generator, loss of fuel gas shall cut off the combustion air.

4-2.2.5 Where a secondary air adjustment is provided, adjustment shall include a locking device to prevent an unintentional change in setting.

4-2.3 Fuel Gas Supply Piping.

4-2.3.1 A remotely located shutoff valve shall be provided to allow the fuel to be turned off in an emergency and shall be located so that fire or explosion at a furnace does not prevent access to this valve.

4-2.3.2 Installation of LP-Gas storage and handling systems shall comply with NFPA 58, *Liquefied Petroleum Gas Code.*

4-2.3.3 Piping from the point of delivery to the equipment isolation valve shall comply with NFPA 54, *National Fuel Gas Code.* *(See 4-2.4.2.)*

4-2.4 Equipment Fuel Gas Piping.

4-2.4.1 Manual Shutoff Valves and Cocks.

4-2.4.1.1 Individual manual shutoff valves for equipment isolation shall be provided for shutoff of the fuel to each piece of equipment.

4-2.4.1.2 Manual shutoff valves shall have permanently affixed visual indication of the valve position.

4-2.4.1.3 Quarter-turn valves with removable wrenches shall not allow the wrench handle to be installed perpendicular to the fuel gas line when the valve is open.

4-2.4.1.4 It shall be the user's responsibility to ensure that separate wrenches (handles) remain affixed to the valve and that they are oriented properly with respect to the valve port.

4-2.4.1.5 Valves and cocks shall be maintained and lubricated in accordance with the manufacturer's instructions.

4-2.4.2 Piping and Fittings.

4-2.4.2.1 Material for the piping and fittings that connect the equipment manual isolation valve to the burner shall meet the requirements of NFPA 54, *National Fuel Gas Code*.

4-2.4.2.2 Piping, fittings, and valves shall be sized to provide proper flow rates and pressure so as to maintain a stable flame over the burner operating range.

4-2.4.3* Fuel Filters and Strainers. For new installations, a gas filter or strainer shall be installed in the fuel gas piping to protect the downstream safety shutoff valves.

4-2.4.4* Drip Legs. A drip leg or sediment trap shall be installed for each fuel gas supply line prior to any piping devices. The drip leg shall be at least 3 in. (76 mm) long and the same diameter as the supply piping.

4-2.4.5 Pressure Regulators and Pressure Switches.

4-2.4.5.1 A pressure regulator shall be furnished wherever the plant supply pressure exceeds that required for proper burner operation or wherever the plant supply pressure is subject to excessive fluctuations.

Exception: An automatic flow control valve shall be permitted to meet this requirement, provided it can compensate for the full range of expected source pressure variations.

4-2.4.5.2 Regulators and switches shall be vented to a safe location where vented gas cannot re-enter the building without extreme dilution. The terminating end shall be protected against water entry and shall be bug-screened. Vent piping shall be of adequate size to allow normal regulator and switch operation.

Exception No. 1: Vent piping from regulators and switches shall be permitted to terminate within a building where used with lighter-than-air fuel gases, provided the vent contains a restricted orifice and discharges into a space large enough and with sufficient natural ventilation so that the escaping gases do not present a hazard and cannot re-enter the work area without extreme dilution.

Exception No. 2: Vent piping shall not be required for regulators and switches where used with lighter-than-air fuel gases at 1 psig (7 kPa) inlet pressure or less, provided the vent connection contains a restricted orifice and discharges into a space large enough, or is ventilated well enough, so that the escaping gases do not present a hazard.

Exception No. 3: Fuel gas regulators and zero governors shall not be required to be vented if backloaded from combustion air lines, air–gas mixture lines, or combustion chambers, provided that gas leakage through the backload connection does not create a hazard.

4-2.4.5.3 Fuel gas regulators and zero governors shall not be backloaded from oxygen or oxygen-enriched air lines.

4-2.4.5.4 Vent lines from multiple furnaces shall not be manifolded together.

4-2.4.5.5 Vent lines from multiple regulators and switches of a single furnace, where manifolded together, shall be piped in such a manner that diaphragm rupture of one vent line does not backload the others. The size of the vent manifold shall be not less than the area of the largest vent line plus 50 percent of the additional vent line area.

4-2.5 Flow Control Valves. Where the minimum or the maximum flow of combustion air or the fuel gas is critical to the safe operation of the burner, flow valves shall be equipped with an appropriate limiting means and with a locking device to prevent an unintentional change in the setting.

4-2.6 Air–Fuel Gas Mixers.

4-2.6.1* General. Subsection 4-2.6 shall apply only to mixtures of fuel gas with air and not to mixtures of fuel gas with oxygen or oxygen-enriched air. Oxygen shall not be introduced into air–fuel gas mixture piping, fuel gas mixing machines, or air–fuel gas mixers.

4-2.6.2 Proportional Mixing.

4-2.6.2.1 Piping shall be designed to provide a uniform mixture flow of proper pressure and velocity as needed for stable burner operation.

4-2.6.2.2 Valves or other obstructions shall not be installed between a proportional mixer and burners. Fixed orifices shall be permitted for purposes of balancing.

4-2.6.2.3 Any field-adjustable device built into a proportional mixer (e.g., gas orifice, air orifice, ration valve) shall be arranged with an appropriate locking device to prevent unintentional changes in the setting.

4-2.6.2.4 Where a mixing blower is used, an approved safety shutoff valve shall be installed in the fuel gas supply connection that shuts off the fuel gas supply automatically when the blower is not in operation and in the event of a fuel gas supply failure.

4-2.6.2.5 Mixing blowers shall not be used with fuel gases containing more than 10 percent free hydrogen (H_2).

4-2.6.2.6 Mixing blowers having a static delivery pressure of more than 10 in. w.c. (2.49 kPa) shall be considered mixing machines.

4-2.6.3 Mixing Machines.

4-2.6.3.1* Automatic fire checks shall be provided in piping systems that distribute flammable air–fuel gas mixtures from a mixing machine. The automatic fire check shall be installed as close as practical to the burner inlet(s), and the manufacturer's installation guidelines shall be followed.

4-2.6.3.2 A separate, manually operated gas valve shall be provided at each automatic fire check for shutting off the flow of air-fuel mixture through the fire check after a flashback has occurred. The valves shall be located upstream as close as practicable to the inlet**s** of the automatic fire checks.

CAUTION

These valves shall not be reopened after a flashback has occurred until the fire check has cooled sufficiently to prevent reignition of the flammable mixture and has been properly reset.

4-2.6.3.3* A backfire arrester with a safety blowout device shall be provided near the outlet of each mixing machine that produces a flammable air–fuel gas mixture. The manufacturer's installation guidelines shall be followed.

4-2.6.3.4 A listed safety shutoff valve shall be installed in the fuel gas supply connection of any mixing machine. This valve shall be arranged to shut off the fuel gas supply automatically when the mixing machine is not in operation or in the event of an air or fuel gas supply failure.

Exception: Where listed safety shutoff valves are not available for the service intended, the selected device shall require approval by the authority having jurisdiction.

4-2.7 Fuel Gas Burners.

4-2.7.1 All burners shall maintain the stability of the designed flame shape, without flashback or blow-off, over the entire range of turndown that is encountered during operation where supplied with combustion air (oxygen-enriched air or oxygen) and the designed fuels in the proper proportions and in the proper pressure ranges. Burners shall only be used with the fuels for which they are designed.

4-2.7.2 All pressures required for safe operation of the combustion system shall be maintained within the proper ranges throughout the firing cycle.

4-2.7.3 Burners shall have the ignition source sized and located in a position that provides safe and reliable ignition of the pilot or main flame.

4-2.7.3.1 Self-piloted burners shall have a safe and reliable transition from pilot flame to main flame.

4-2.7.3.2 For burners that cannot be ignited safely at all firing rates, positive provision shall be made to reduce the burner firing rates during light-off to a lower level, which ensures a safe and reliable ignition of the main flame (forced low-fire start).

4-2.7.4* Explosion resistance of nonmetallic radiant tubes shall be determined by test.

4-2.8 Fuel Ignition.

4-2.8.1* The ignition source (e.g., electric spark, hot wire, pilot burner, handheld torch) shall be applied effectively at the proper point and with sufficient intensity to ignite the air-fuel mixture.

4-2.8.2 Fixed ignition sources shall be mounted to prevent unintentional changes in location and in direction with respect to the main flame.

4-2.8.3 Pilot burners shall be considered burners, and all provisions of Section 4-2 shall apply.

4-2.9 Dual-Fuel and Combination Burners. Where fuel gas and fuel oil are to be fired individually (dual-fuel) or simultaneously (combination), the provisions of Sections 4-2, 4-3, and 5-12 shall apply equally to the respective fuels.

4-3 Oil-Fired Units.

4-3.1 Scope.

4-3.1.1* Section 4-3 shall apply to combustion systems for furnaces fired with No. 2, No. 4, No. 5, and No. 6 industrial fuel oils as specified by ASTM D 396, *Standard Specifications for Fuel Oils*. It also includes the oil-burning portions of dual-fuel and combination burners.

4-3.1.2 Additional considerations that are beyond the scope of this standard shall be given to other combustible liquids not specified in 4-3.1.1.

4-3.1.3 Burners, along with associated valving, safety controls, and other auxiliary components, shall be suitable for the type and pressure of the fuel oil to be used and for the temperatures to which they are subjected.

4-3.2* Combustion Air.

4-3.2.1 The fuel-burning system design shall provide for an adequate supply of clean combustion air for proper burner operation.

4-3.2.2 Precautions shall be taken to prevent insufficiently diluted products of combustion from short-circuiting back into the combustion air. This requirement shall not prevent the use of properly designed flue gas recirculation systems.

4-3.2.3 Where primary or secondary combustion air is provided mechanically, combustion airflow or pressure shall be proven and interlocked with the safety shutoff valves so that oil cannot be admitted prior to establishment of combustion air and so that the oil is shut off in the event of combustion air failure.

4-3.2.4 Where a secondary air adjustment is provided, adjustment shall include a locking device to prevent an unintentional change in setting.

4-3.3 Oil Supply Piping.

4-3.3.1 Storage tanks, their installation, and their supply piping materials shall comply with NFPA 31, *Standard for the Installation of Oil-Burning Equipment*.

4-3.3.2 A remotely located shutoff valve shall be provided to allow the fuel to be turned off in an emergency and shall be located so that fire or explosion at a furnace does not prevent access to this valve. A positive displacement oil pump shall be permitted to serve as a valve by shutting off its power.

4-3.3.3 Where a shutoff is installed in the discharge line of an oil pump that is not an integral part of a burner, a pressure-relief valve shall be connected to the discharge line between the pump and the shutoff valve and arranged to return surplus oil to the supply tank or to bypass it around the pump, unless the pump includes an internal bypass.

4-3.3.4* All air from the supply and return piping shall be purged initially, and air entrainment in the oil shall be minimized.

4-3.3.5 Suction, supply, and return piping shall be adequately sized with respect to oil pump capacity.

4-3.3.6* Wherever a section of oil piping can be shut off at both ends, relief valves or expansion chambers shall be used to release the pressure caused by thermal expansion of the oil.

4-3.4 Equipment Oil Piping.

4-3.4.1 Manual Shutoff Valves and Cocks.

4-3.4.1.1 Individual manual shutoff valves for equipment isolation shall be provided for shutoff of the fuel to each piece of equipment.

4-3.4.1.2 Manual shutoff valves shall be installed to avoid oil spillage during servicing of supply piping and associated components.

4-3.4.1.3 Manual shutoff valves shall display a permanently affixed visual indication of the valve position.

4-3.4.1.4 Quarter-turn valves with removable wrenches shall not allow the wrench handle to be installed perpendicular to the fuel oil line when the valve is open.

4-3.4.1.5 It shall be the user's responsibility to ensure that separate wrenches (handles) remain affixed to the valve and that they are oriented properly with respect to the valve port.

4-3.4.1.6 Valves and cocks shall be maintained and lubricated in accordance with the manufacturer's instructions.

4-3.4.2 Piping and Fittings.

4-3.4.2.1 Equipment piping shall be in accordance with NFPA 31, *Standard for the Installation of Oil-Burning Equipment.*

4-3.4.2.2 Piping, fittings, and valves shall be sized to provide proper flow rates and pressure so as to maintain a stable flame over the burner operating range.

4-3.4.3 Oil Filters and Strainers.

4-3.4.3.1 An oil filter or strainer shall be installed in the oil piping to protect the downstream components.

4-3.4.3.2* The degree of filtration shall be compatible with the size of the most critical clearance being protected.

4-3.4.3.3 The filter or strainer shall be suitable for the intended pressure, temperature, and service.

4-3.4.4 Pressure Regulators. A pressure regulator shall be furnished wherever the plant supply pressure exceeds that required for proper burner operation or wherever the plant supply pressure is subject to excessive fluctuations.

Exception: An automatic flow control valve shall be permitted to meet this requirement, provided it can compensate for the full range of expected source pressure variations.

4-3.4.5* Pressure Gauges. Pressure gauges shall be isolated or protected from pulsation damage during operation of the burner system.

4-3.5 Flow Control Valves. Where the minimum or the maximum flow of combustion air or the fuel oil is critical to the safe operation of the burner, flow valves shall be equipped with an appropriate limiting means and with a locking device to prevent an unintentional change in the setting.

4-3.6 Oil Atomization.

4-3.6.1* Oil shall be atomized to droplet size as required for proper combustion throughout the firing range.

4-3.6.2 The atomizing device shall be accessible for inspection, cleaning, repair, replacement, and other maintenance as required.

4-3.7 Oil Burners.

4-3.7.1 All burners shall maintain the stability of the designed flame shape over the entire range of turndown that is encountered during operation where supplied with combustion air (oxygen-enriched air or oxygen) and the designed fuels in the proper proportions and in the proper pressure ranges.

4-3.7.2 All pressures required for the safe operation of the combustion system shall be maintained within the proper ranges throughout the firing cycle.

4-3.7.3 The burner shall be supplied with fuel oil of the proper grade that has been preconditioned to the required viscosity.

4-3.7.4 Burners shall have the ignition source sized and located in a position that provides safe and reliable ignition of the pilot or main flame.

4-3.7.4.1 Self-piloted burners shall have a safe and reliable transition from pilot flame to main flame.

4-3.7.4.2 For burners that cannot be ignited safely at all firing rates, positive provision shall be made to reduce the burner firing rates during light-off to a lower level, which ensures a safe and reliable ignition of the main flame (forced low-fire start).

4-3.7.5 If purging of oil passages upon normal termination of a firing cycle is required, it shall be done prior to shutdown with the initial ignition source present and with all associated fans and blowers in operation.

4-3.8 Fuel Ignition.

4-3.8.1* The ignition source (e.g., electric spark, hot wire, pilot burner, handheld torch) shall be applied effectively at the proper point and with sufficient intensity to ignite the air-fuel mixture.

4-3.8.2 Fixed ignition sources shall be mounted so as to prevent unintentional changes in location and in direction with respect to the main flame.

4-3.8.3 Pilot burners shall be considered burners, and all provisions of Section 4-2 shall apply.

4-3.9 Dual-Fuel and Combination Burners. Where fuel gas and fuel oil are to be fired individually (dual-fuel) or simultaneously (combination), the provisions of Sections 4-2, 4-3, and 5-12 shall apply equally to the respective fuels.

4-4 Oxygen-Enhanced Fuel-Fired Units.

4-4.1* Scope. Section 4-4 shall apply to combustion systems using oxygen (oxy-fuel) or oxygen-enriched air with gas or liquid fuels. The requirements shall be in addition to those in Sections 4-2 and 4-3 and Chapter 5.

4-4.2 Combustion Systems Utilizing Oxygen.

4-4.2.1 Oxygen storage and delivery systems shall comply with NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites.*

4-4.2.2 Oxygen shall not be introduced into inlet or discharge piping of air compressors or blowers that are internally lubricated with petroleum oils, greases, or other combustible substances.

4-4.3 Oxygen Piping and Components.

4-4.3.1 Design, materials of construction, installation, and tests of oxygen piping shall comply with the applicable sections of ASME B31.3, *Process Piping*.

4-4.3.2* Materials and construction methods used in the installation of the oxygen piping and components shall be compatible with oxygen.

4-4.3.3* Piping and components that come in contact with oxygen shall be cleaned prior to admitting gas.

4-4.3.4* Air introduced into oxygen passages in burners, such as cooling air, shall be free of particulate matter, oil, grease, and other combustible materials.

4-4.3.5 A remotely located shutoff valve shall be provided to allow the oxygen to be turned off in an emergency and shall be located so that fire or explosion at a furnace does not prevent access to this valve.

4-4.3.6 Oxygen from pressure-relief devices and purge outlets shall not be released into pipes or manifolds where it can mix with fuel.

4-4.3.7 Oxygen from pressure-relief devices and purge outlets shall be released to a safe location.

4-4.3.8 Means shall be provided to prevent oxygen, fuel, or air to intermix in burner supply lines due to valve leakage, burner plugging, or other system malfunctions.

4-4.3.9* Oxygen piping and components shall be inspected and maintained.

4-4.3.10 If glass tube flowmeters are used in oxygen service, safeguards against personnel injury from possible rupture shall be provided.

4-4.3.11* The piping fed from a cryogenic supply source shall be protected from excessive cooling by means of an automatic low-temperature shutoff device.

4-4.3.12 Piping and controls downstream of an oxygen pressure-reducing regulator shall be able to withstand the maximum potential upstream pressure or shall be protected from overpressurization by means of a suitable pressure-relief device.

4-4.4 Oxygen Flow Control Valves.

4-4.4.1 Where the minimum or the maximum flow of oxygen or oxygen-enriched air is critical to safe operation of the burner, flow control valves shall be equipped with an appropriate limiting means and locking device to prevent an unintentional change in the setting.

4-4.4.2 An oxygen pressure regulator shall be furnished wherever the source oxygen pressure exceeds that required for proper burner operation or wherever the source pressure is subject to excessive fluctuations.

Exception: An automatic flow control valve shall be permitted to meet this requirement, provided it can compensate for the full range of expected source pressure variations and complies with 4-4.4.1.

4-4.5 Oxygen-Enriched Combustion Air.

4-4.5.1 Filters shall be installed in the air blower intake to minimize contamination of the oxygen-enriched air piping.

4-4.5.2* Devices, such as diffusers, used to disperse oxygen into an airstream shall be designed to prevent jet impingement of oxygen onto interior surfaces of the air piping.

4-4.5.3 Oxygen-enriched combustion air shall not be introduced into a burner before the oxygen has been uniformly mixed into the airstream.

4-4.5.4 Branching of the enriched-air piping shall not be permitted before a uniform mixture of oxygen and air has been attained.

4-5 Flue Product Venting.

4-5.1 A means shall be provided to ensure adequate ventilation for the products of combustion on fuel-fired equipment.

4-5.2 Collecting and venting systems for radiant tube–type heating systems shall be of sufficient capacity to prevent an explosion or fire hazard due to the flow of unburned fuel through the radiant tubes. The system shall be capable of dilution of the rated maximum input capacity of the system to a noncombustible state.

Exception: These requirements shall not apply to radiant tube–type heating systems provided with two safety shutoff valves interlocked with combustion safeguards.

4-6 Electrically Heated Units.

4-6.1 Scope. Section 4-6 includes all types of heating systems where electrical energy is used as the source of heat.

4-6.2 Safety Equipment. Safety equipment, including airflow interlocks, time relays, and temperature switches, shall be in accordance with Chapter 5.

4-6.3* Electrical Installation. All parts of the electrical installation shall be in accordance with NFPA 70, *National Electrical Code*.

4-6.4 Resistance Heating Systems.

4-6.4.1 The provisions of 4-6.4 shall apply to resistance heating systems, including infrared lamps, such as quartz, ceramic, and tubular glass types.

4-6.4.2 Construction.

4-6.4.2.1 The heater housing shall be constructed so as to provide access to heating elements and wiring.

4-6.4.2.2 Heating elements and insulators shall be supported securely or fastened so that they do not become easily dislodged from their intended location.

4-6.4.2.3 Heating elements that are electrically insulated from and supported by a metallic frame shall have the frame electrically grounded.

4-6.4.2.4 Open-type resistor heating elements shall be supported by electrically insulated hangers and shall be secured to prevent the effects of motion induced by thermal stress, which could result in adjacent segments of the elements touching one another, or the effects of touching a grounded surface.

4-6.4.2.5 External parts of furnace heaters that are energized at voltages that could be hazardous as specified in NFPA 70, *National Electrical Code*, shall be guarded.

4-6.4.3 Heater Locations. Heaters shall not be located directly under the product being heated where combustible materials can drop and accumulate.

4-6.5 Induction and Dielectric Heating Systems.

4-6.5.1 Induction and dielectric heating systems shall be designed and installed in accordance with NFPA 70, *National Electrical Code*, with special reference to Article 665.

4-6.5.2 Construction.

4-6.5.2.1* Combustible electrical insulation shall be reduced to a minimum.

4-6.5.2.2 Protection shall be installed to prevent overheating of any part of the equipment in accordance with NFPA 70, *National Electrical Code*.

4-6.5.2.3 Where water-cooling is used for transformers, capacitors, electronic tubes, spark gaps, or high-frequency conductors, cooling coils and connections shall be arranged so that leakage or condensation does not damage the electrical equipment. The cooling-water supply shall be interlocked with the power supply so that loss of water cuts off the power supply. Consideration shall be given to providing individual pressure flow interlocks for parallel waterflow paths.

4-6.5.2.4 Where forced ventilation by motor-driven fans is necessary, the air supply shall be interlocked with the power supply. An air filter shall be provided at the air intake.

4-6.5.2.5 The conveyor motor and the power supply of dielectric heaters of the conveyor type used to heat combustible materials shall be interlocked to prevent overheating of the material being treated.

4-6.5.2.6 Dielectric heaters used for treating highly combustible materials shall be designed to prevent a disruptive discharge between the electrodes.

4-7 Fluid-Heated Systems.

4-7.1* Scope. Section 4-7 shall apply to all types of systems where water, steam, or other heat transfer fluids are the source of heat through the use of heat exchangers. Section 4-7 covers the heat transfer fluid system between the oven supply and return isolation valves for the oven being served.

4-7.2 General.

4-7.2.1* Piping and fittings shall be in accordance with ASME B31.1, *Power Piping*.

4-7.2.2 Piping containing combustible heat transfer fluid that is insulated shall use closed-cell, nonabsorptive insulation. Fibrous or open-cell insulation shall not be permitted.

4-7.2.3* Oven isolation valves shall be installed in the fluid supply and return lines. If a combustible heat transfer fluid is used, the oven isolation valves shall be installed within 5.0 ft (1.5 m) of the oven.

4-7.2.4 Enclosures or ductwork for heat exchanger coils shall be of noncombustible construction with suitable access openings provided for maintenance and cleaning.

4-7.2.5 Heat exchangers or steam coils shall not be located on the floor of an oven or in any position where paint drippage or combustible material can accumulate on the coils.

4-7.3 Safety Devices.

4-7.3.1 System equipment shall be operated within the temperature and pressure limits specified by the supplier or manufacturer of the heat transfer medium and by the manufacturer of the equipment.

4-7.3.2 If the oven atmosphere is recirculated over the heat exchanger coils, a noncombustible filtration system shall be used if combustible particulates can deposit on the heat exchanger surface. The filtration system and heat exchanger shall be cleaned on a regular schedule.

4-8 Heating Elements.

4-8.1* The design of heating elements can take several forms, such as rods, bars, sheets, or cloth, but shall be limited to materials that do not vaporize under minimum vacuum and maximum temperature.

4-8.2 Electrical heating equipment in a vacuum furnace shall not be operable until a sufficient vacuum level has been attained inside the furnace chamber to provide protection for the furnace elements, radiant shields, or insulation.

4-8.3* Heating element support hangers and insulators shall be of compatible materials to provide electrical insulation and nonreacting materials at specified vacuum levels and temperatures.

4-8.4 Heating element connections shall be designed to minimize arcing and disassembly problems.

4-8.5 The heating element power terminal and vessel feedthrough shall be designed with consideration for vacuum integrity and heating effects. Vacuum mating surfaces shall be free from dirt and scratches and equivalent to O-ring designs.

4-8.6 Power terminal connection points to power supply cables shall be covered or housed to prevent high-current electrical hazard to personnel.

4-9* Furnace Thermal Insulation and Heat Shields.

4-9.1* Insulation shall not break down at specified vacuum levels and temperatures.

4-9.2* Multiple layers of metal heat shields shall be acceptable, assuming these materials comply with temperature and vacuum requirements.

4-9.3* Insulation shall be installed so as to prevent it from breaking up and becoming airborne, in which case it can block heat exchangers and cause vacuum valve seals to leak on furnaces that use forced gas quenching.

Chapter 5 Safety Equipment and Application

5-1 Scope.

5-1.1 Chapter 5 shall apply to safety equipment and its application to furnace heating and ventilation systems. Section 5-3 shall apply to all safety controls included in this standard.

5-1.2* For the purpose of this chapter, the term *furnace heating system* shall include the heating source, associated piping and wiring used to heat the furnace, auxiliary quenches, and the work therein.

5-2 General.

5-2.1 All safety devices shall be listed for the service intended. Safety devices shall be applied and installed in accordance with this standard and the manufacturer's instructions.

Exception: Where listed devices are not available for the service intended, the selected device shall require approval by the authority having jurisdiction.

5-2.2 Electric relays and safety shutoff valves shall not be used as substitutes for electrical disconnects and manual shutoff valves.

5-2.3 Purge, ignition trials, and other burner safety sequencing shall be performed only by devices listed for such service.

5-2.4 A shutdown of the heating system by any safety feature or safety device shall require manual intervention of an operator for re-establishment of normal operation of the system.

5-2.5 Regularly scheduled inspection, testing, and maintenance of all safety devices shall be performed. *(See Chapter 11.)*

5-2.5.1 It shall be the responsibility of the equipment manufacturer to provide operating instructions that cover start-up, shutdown, emergencies, and procedures for inspection, testing, and maintenance.

5-2.5.2 It shall be the responsibility of the user to establish, schedule, and enforce the frequency and extent of the inspection, testing, and maintenance program, as well as the corrective action to be taken. Documented safety inspections and testing shall be performed at least annually.

5-2.6 Safety devices shall be installed, used, and maintained in accordance with the manufacturer's instructions.

5-2.7 All combustion safety circuitry contacts for required safety interlocks and excess temperature limit controllers shall be arranged in series ahead of the safety shutoff valve holding medium.

Exception No. 1: Devices specifically listed for combustion safety service shall be permitted to be used in accordance with the listing requirements and the manufacturer's instructions.

Exception No. 2: Interposing relays shall be permitted where the conditions of (a), (b), and (c) are met:

(a) Required connected load exceeds the rating of available safety interlock devices or where necessary to perform required safety logic functions

(b) Interposing relay is configured to revert to a safe condition upon loss of power

(c) Each interposing relay serves no more than one safety interlock device

5-2.8 Safety devices shall be located or guarded to protect them from physical damage.

5-2.9 Safety devices shall not be removed or rendered ineffective.

5-2.10 Safety devices shall not be bypassed electrically or mechanically. This requirement shall not prohibit safety device testing and maintenance in accordance with 5-2.5. When a system includes a "built-in" test mechanism that bypasses any safety device, it shall be interlocked to prevent operation of the system while the device is in the test mode, unless listed for that purpose.

5-2.11* Electrical power for safety control circuits shall be single-phase, one-side grounded, with all breaking contacts in the "hot" ungrounded, fuse-protected, or circuit breaker–protected line, and shall not exceed 120-volt potential.

5-3 Programmable Controllers for Safety Service.

5-3.1 General.

5-3.1.1 The supplier of the application software for the programmable controller shall provide the end user and the authority having jurisdiction with the documentation needed to verify that all related safety devices and safety logic are functional before the programmable controller is placed in operation.

5-3.1.2 In the event of a power failure, the programmable controller (hardware and software) shall not prevent the system from reverting to a safe default condition. A safe condition shall be maintained upon the restoration of power.

5-3.1.3 The control system shall have a separate manual emergency switch, independent of the programmable controller, that initiates a safe shutdown.

CAUTION

For some applications, additional manual action might be required to bring the process to a safe condition.

5-3.1.4 Any changes to hardware or software shall be documented, approved, and maintained in a file on the site.

5-3.1.5 The internal status of the programmable controller shall be monitored. In the event of a programmable controller failure, the system shall annunciate and cause the system to revert to a safe condition.

5-3.1.6 The system access shall be limited by incorporating measures to prevent unauthorized access to the programmable controller or its logic that could result in hazards to personnel or equipment.

CAUTION

Modems and networks require special measures to provide the necessary security.

5-3.2 Combustion Safety Functions.

5-3.2.1 Programmable controller–based systems specifically listed for combustion safety service shall be permitted where applied in accordance with the listing requirements and the manufacturer's instructions.

5-3.2.2 A programmable controller not listed for combustion safety service shall be permitted to monitor safety interlocks, or to provide burner control functions, provided that its use complies with both of the following:

(1) The programmable controller shall not interfere with or prevent the operation of the safety interlocks.
(2) Only isolated programmable controller contacts (not directly connected to a power source) shall be permitted to be wired in series with the safety interlocks to permit burner control functions.

5-3.2.3 The requirements of 5-2.3 shall apply to programmable controller–based systems.

5-3.3 Hardware.

5-3.3.1* A failure of programmable controller hardware shall cause the system to revert to a safe default condition.

5-3.3.2 A programmable controller shall be provided with a watchdog timer external to the CPU and memory. Failures detected by the watchdog timer shall cause the system to revert to a safe default condition.

5-3.3.3 System operation shall be tested and verified for compliance with this standard and the original design criteria whenever the programmable controller is replaced, repaired, or updated.

5-3.4 Software.

5-3.4.1 Whenever application software that contains safety logic or detection logic is modified, system operation shall be verified for compliance with this standard and the original design criteria.

5-3.4.2 The software for the programmable controller shall reside in some form of nonvolatile storage (memory that retains information on loss of system power).

5-3.4.3 Application software that contains safety logic shall be separated from all other programming. Application software that interacts with safety logic or detection logic for input/output devices shall be separated from all other programming.

5-3.4.4 Unauthorized change or corruption of software shall cause the system to revert to a safe default condition.

5-4 Safety Control Application for Fuel-Fired Heating Systems.

5-4.1 Preignition (Prepurge, Purging Cycle).

5-4.1.1 Prior to each furnace heating system start-up, provision shall be made for the removal of all flammable vapors and gases that might have entered the heating chambers during the shutdown period.

5-4.1.2 A timed preignition purge shall be provided. At least 4 standard cubic feet (scf) of fresh air or inert gas per cubic foot (4 m^3/m^3) of heating chamber volume shall be introduced during the purging cycle.

5-4.1.2.1 To begin the timed preignition purge interval, both of the following conditions shall be satisfied:

(1) The minimum required preignition airflow shall be proven *(see Sections 5-5 and 5-6 for proof of airflow requirements).*
(2) The safety shutoff valve(s) shall be closed *(see 5-7.2.2 and 5-7.3.2 for proof of closure requirements).*

5-4.1.2.2 The minimum required preignition purge airflow shall be proven and maintained throughout the timed preignition purge interval.

5-4.1.2.3 Failure to maintain the minimum required preignition purge airflow shall stop the preignition purge and reset the purge timer.

5-4.1.3 A furnace heating system, either alone or as part of multiple furnaces feeding into one fume incinerator, shall not be purged into an operating incinerator.

Exception: A furnace heating system shall be permitted to be purged into an operating incinerator if it can be demonstrated that the flammable vapor concentration entering the fume incinerator cannot exceed 50 percent of the LEL.

5-4.1.4 Preignition purging of radiant tube–type heating systems shall be provided.

Exception: Preignition purging of radiant tube–type heating systems shall not be required where the systems are arranged and designed such that the conditions of (a) or (b) are satisfied.

(a) The tubes are of metal construction and open at one or both ends with heat recovery systems, if used, that are of explosion-resistant construction.

(b) The entire radiant tube heating system, including any associated heat recovery system, is of explosion-resistant construction.

5-4.1.5 Prior to the reignition of a burner after a burner shutdown or flame failure, a preignition purge shall be accomplished.

Exception: Repeating the preignition purge shall not be required where the conditions of (a), (b), or (c) are satisfied.

(a) The heating chamber temperature exceeds 1400°F (760°C).

(b) For any fuel-fired system, all of the following conditions are satisfied: (1) each burner and pilot is supervised by a combustion safeguard in accordance with Section 5-9; (2) each burner system is equipped with safety shutoff valves in accordance with Section 5-7; and (3) at least one burner remains operating in the common combustion chamber of the burner to be reignited.

(c) All of the following conditions are satisfied (does not apply to fuel oil systems): (1) each burner and pilot is supervised by a combustion safeguard in accordance with Section 5-9; (2) each burner system is equipped with gas safety shutoff valves in accordance with Section 5-7; and (3) it can be demonstrated that the combustible concentration in the heating chamber cannot exceed 25 percent of the LEL.

CAUTION

Repeated ignition attempts can result in a combustible concentration greater than 25 percent of the LEL. Liquid fuels can accumulate, causing additional fire hazards.

5-4.2 Trial-for-Ignition Period.

5-4.2.1 The trial-for-ignition period of the pilot burner shall not exceed 15 seconds.

5-4.2.2 The trial-for-ignition period of the main gas burner shall not exceed 15 seconds.

Exception: The trial-for-ignition period of the main gas burner shall be permitted to exceed 15 seconds, where both of the following conditions are satisfied.

(a) A written request for an extension of trial for ignition is approved by the authority having jurisdiction.

(b) It is determined that 25 percent of the LEL cannot be exceeded in the extended time.

5-4.2.3 The trial-for-ignition period of the main oil burner shall not exceed 15 seconds.

5-5 Ventilation Safety Devices.

5-5.1 Wherever a fan is essential to the operation of the oven or allied equipment, fan operation shall be proven and interlocked into the safety circuitry.

5-5.1.1 Electrical interlocks and flow switches shall be arranged in the safety control circuit so that loss of ventilation or airflow immediately shuts down the heating system of the affected section, or, if necessary, loss of ventilation shall shut down the entire heating system as well as the conveyor.

5-5.1.2 Air pressure switches shall not be used to prove airflow where dampers downstream of the pressure switch can be closed to the point of reducing flow to an unsafe operating level.

5-5.1.3 Air suction switches shall not be used to prove airflow where dampers upstream of the pressure switch can be closed to the point of reducing flow to an unsafe operating level.

5-5.1.4 Switches used to prove airflow on systems where the air is contaminated with any substance that might condense or otherwise create a deposit shall be selected and installed to prevent interference with the performance of the switch.

5-5.2 Dampers capable of being adjusted to a position that can result in an unsafe condition shall be equipped with mechanical stops, cut-away dampers, or limit switches interlocked into the safety circuitry to ensure that dampers are in a proper operating position.

5-6 Combustion Air Safety Devices.

5-6.1 Where the air from the exhaust or recirculating fans is required for combustion of the fuel, airflow shall be proven prior to an ignition attempt. Reduction of airflows to an unsafe level shall result in closure of the safety shutoff valves.

5-6.2 Where a combustion air blower is used, the minimum combustion air needed for proper burner operation shall be proven prior to each attempt at ignition.

5-6.3 Motor starters on equipment required for the combustion of the fuel shall be interlocked into the combustion safety circuitry.

5-6.4* A low pressure switch shall be used to sense and monitor combustion air pressure or differential pressure and shall be interlocked into the combustion safety circuitry.

Exception: Alternative methods of verification of minimum combustion air required for burner operation shall be permitted where both of the following conditions are satisfied.

(a) Burner can reliably operate at a combustion air pressure that is lower than the available range of pressure switches listed for this service.

(b) Alternative method is acceptable to the authority having jurisdiction.

5-6.5 Wherever it is possible for combustion air pressure to exceed a maximum safe operating pressure, as might occur where compressed air is utilized, a high pressure switch interlocked into the combustion safety circuitry shall be used.

5-7 Safety Shutoff Valves (Fuel Gas or Oil).

5-7.1 General.

5-7.1.1 Safety shutoff valves shall be utilized as a key safety control to protect against explosions and fires.

5-7.1.2 Each safety shutoff valve required in 5-7.2.1 and 5-7.3.1 shall automatically shut off the fuel to the burner system after interruption of the holding medium (such as electric current or fluid pressure) by any one of the interlocking safety devices, combustion safeguards, or operating controls.

Exception: For fuel gas systems, where multiple burners or pilots operate as a burner system firing into a common heating chamber, the loss of flame signal at one or more burners shall be permitted to shut off those burner(s) by closing a single safety shutoff valve provided the following conditions in both (a) and (b) are satisfied.

(a) For the individual burner safety shutoff valve: (1) it is demonstrated based on available airflow that failure of the valve to close will result in a fuel concentration not greater than 25 percent of the LEL; or (2) the safety shutoff valve has proof of closure acceptable to the authority having jurisdiction; or (3) the fuel to the burner is monitored to verify that there is no fuel flow following operation of the burner safety shutoff valve.

(b) The safety shutoff valve upstream of the individual burner safety shutoff valves shall close for any of the following conditions: (1) activation of any operating control or interlocking safety device other than the combustion safeguard; or (2) when the individual burner valves do not have proof of closure or fuel monitoring as described in (a) and the number of failed burners are capable of exceeding 25 percent of the LEL if their single safety shutoff valves should fail in the open position; or (3) when individual burner valves have proof of closure or fuel monitoring as described in (a) and verification that the individual burner safety shutoff valve has closed following loss of flame signal at the burner is not present; or (4) loss of flame signal at all burners in the burner system or at a number of burners in the burner system that will result in unsafe operation.

5-7.1.3 Safety shutoff valves shall not be used as modulating control valves.

Exception: The use of listed safety shutoff valves designed as both a safety shutoff valve and a modulating valve, and tested for concurrent use, shall be permitted.

5-7.1.4 Valve components shall be of a material suitable for the fuel handled and for ambient conditions.

5-7.1.5 Safety shutoff valves in systems containing particulate matter or highly corrosive fuel gas shall be operated regularly in accordance with the manufacturer's instructions to assure their proper operation.

5-7.1.6 Valves shall not be subjected to pressures in excess of the manufacturer's ratings.

5-7.1.7 If normal inlet pressure to the fuel pressure regulator immediately upstream from the valve exceeds the valve's pressure rating, a relief valve shall be provided and it shall be vented to a safe location.

5-7.1.8 Local visual position indication shall be provided at each safety shutoff valve to burners or pilots in excess of 150,000 Btu/hr (44 kW). This indication shall directly indicate the physical position, closed and open, of the valve. Where lights are used for position indication, the absence of light shall not be used to indicate open or closed position. Indirect indication of valve position, such as by monitoring operator current voltage or pressure, shall not be permitted.

5-7.2 Fuel Gas Safety Shutoff Valves.

5-7.2.1 Each main and pilot fuel gas burner system shall be separately equipped with two safety shutoff valves piped in series.

Exception: A *single safety shutoff valve shall be permitted on a radiant tube–fired burner system where the following conditions of (a) or (b) are satisfied.*

(a) The tubes are of metal construction and open at one or both ends with heat recovery systems, if used, that are of explosion-resistant construction.

(b) The entire radiant tube heating system, including any associated heat recovery system, is of explosion-resistant construction.

5-7.2.2 Where the main or pilot fuel gas burner system capacity exceeds 400,000 Btu/hr (117 kW), at least one of the safety shutoff valves required by 5-7.2.1 shall be proved closed and interlocked with the preignition purge interval. *(See 5-4.1.2.1.)*

5-7.2.3* A permanent and ready means for making tightness checks of all fuel gas safety shutoff valves shall be provided.

5-7.2.4 Tightness checks shall be performed in accordance with the manufacturer's instructions. Testing frequency shall be at least annually.

5-7.3 Oil Safety Shutoff Valves.

5-7.3.1 Two safety shutoff valves shall be provided under any one of the following conditions:

(1) Where the pressure is greater than 125 psi (862 kPa)
(2) Wherever the fuel oil pump operates without the main oil burner firing, regardless of the pressure
(3) For combination gas and oil burners, where the fuel oil pump operates during the fuel gas burner operation

Where none of the conditions of 5-7.3.1(1) through (3) apply, a single safety shutoff valve shall be permitted.

5-7.3.2 Where two safety shutoff valves are required by 5-7.3.1, at least one of the two safety shutoff valves shall be proved closed and interlocked with the preignition purge interval.

5-8 Fuel Pressure Switches (Gas or Oil).

5-8.1 A low pressure switch shall be provided and shall be interlocked into the combustion safety circuitry.

5-8.2 A high gas pressure switch shall be provided and interlocked into the combustion safety circuitry. The switch shall be located downstream of the final pressure-reducing regulator.

Exception: For an oil system, a high pressure switch shall not be required where the fuel supply pressure to the burners cannot exceed the operating limits of the system.

5-8.3 Pressure switch settings shall be made in accordance with the operating limits of the burner system.

5-9 Combustion Safeguards (Flame Supervision).

5-9.1 Each burner flame shall be supervised by a combustion safeguard having a maximum flame failure response time of 4 seconds or less, that performs a safe-start check, and is interlocked into the combustion safety circuitry.

Exception No. 1: The flame supervision shall be permitted to be switched out of the combustion safety circuitry for a furnace zone when that zone temperature is at or above 1400°F (760°C). When the zone temperature drops below 1400°F (760°C), the burner shall be interlocked to allow its operation only if flame supervision has been re-established. A 1400°F (760°C) bypass controller shall be used for this purpose.

Exception No. 2: Combustion safeguards on radiant tube–type heating systems shall not be required where a suitable means of ignition is provided and the systems are arranged and designed such that the following conditions of (a) or (b) are satisfied.

(a) The tubes are of metal construction and open at one or both ends with heat recovery systems, if used, that are of explosion-resistant construction.

(b) The entire radiant tube heating system, including any associated heat recovery system, is of explosion-resistant construction.

Exception No. 3: Burners without flame supervision shall be permitted, provided these burners are interlocked to prevent their operation when the zone temperature is less than 1400°F (760°C). A 1400°F (760°C) bypass controller shall be used for this purpose.

5-9.2* Flame Supervision.

5-9.2.1 Each pilot and main burner flame shall be supervised independently.

Exception No. 1: One flame sensor shall be permitted to be used to supervise the main burner and pilot flames if an interrupted pilot is used.

Exception No. 2: One flame sensor shall be permitted to be used to supervise self-piloted burners, as defined in Chapter 2.

5-9.2.2* Line burners, pipe burners, and radiant burners, where installed immediately adjacent to one another or connected with suitable flame-propagating devices, shall be considered to be a single burner and shall have at least one flame safeguard installed to sense burner flame at the end of the assembly farthest from the source of ignition.

5-10 Fuel Oil Atomization (Other than Mechanical Atomization).

5-10.1 Adequate pressure of the atomizing medium shall be proven and interlocked into the combustion safety circuitry.

5-10.2 The low pressure switch used to supervise the atomizing medium shall be located downstream from all cocks, valves, and other obstructions that can shut off flow or cause excessive pressure drop of atomization medium.

5-11* Fuel Oil Temperature Limit Devices. Fuel oil temperature limit devices shall be provided and interlocked into the combustion safety circuitry if conditions allow the fuel oil temperature to rise above or fall below a predetermined safe level.

5-12 Multiple Fuel Systems.

5-12.1 Safety equipment in accordance with the requirements of this standard shall be provided for each fuel used. The fact that oil or gas is considered a standby fuel shall not reduce the safety requirements for that fuel.

5-12.2 Where dual-fuel burners are used, positive provision shall be made to prevent the simultaneous introduction of both fuels.

Exception: This requirement shall not apply to combination burners.

5-13 Air–Fuel Gas Mixing Machines.

5-13.1 A safety shutoff valve shall be installed in the fuel gas supply connection of any mixing machine.

5-13.2 The safety shutoff valve shall be arranged to shut off the fuel gas supply automatically when the mixing machine is not in operation or in the event of an air or fuel gas supply failure.

5-14 Oxygen Safety Devices.

5-14.1 Two oxygen safety shutoff valves in series shall be provided in the oxygen supply line.

5-14.2 A filter or fine-mesh strainer shall precede the upstream safety shutoff valve.

5-14.3 There shall be a high oxygen flow or pressure limit interlocked into the combustion safety circuitry. The switch shall be located downstream of the final pressure regulator or automatic flow control valve.

5-14.4 There shall be a low oxygen flow or pressure limit interlocked into the combustion safety circuitry.

5-14.5 The oxygen safety shutoff valves shall shut automatically after interruption of the holding medium by any one of the interlocking safety devices.

5-14.6 Safety shutoff valves shall not be used as modulating control valves.

Exception: The use of listed safety shutoff valves designed as both a safety shutoff valve and a modulating valve, and tested for concurrent use, shall be permitted.

5-14.7 A permanent and ready means for making tightness checks of all oxygen safety shutoff valves shall be provided.

5-14.8 Local visual position indication shall be provided for each oxygen safety shutoff valve to burners or pilots in excess of 150,000 Btu/hr (44 kW). This indication shall directly indicate the physical position, closed and open, of the valve. Where lights are used for position indication, the absence of light shall not be used to indicate open or closed position. Indirect indication of valve position, such as by monitoring operator current voltage or pressure, shall not be permitted.

5-14.9 Oxygen-Enriched Burners.

5-14.9.1 Where oxygen is added to a combustion air line, an interlock shall be provided to permit oxygen flow only when airflow is proven continuously. Airflow shall be proven in accordance with the requirements of Section 5-5.

5-14.9.2 Upon loss of oxygen flow, the flow of fuel shall be permitted to continue where there is no interruption in the flow of combustion air, provided the control system can revert automatically to a safe air–fuel ratio before a hazard due to a fuel-rich flame is created.

5-14.10 Burner systems employing water or other liquid coolants shall be equipped with a low coolant flow limit switch located downstream of the burner and interlocked into the combustion safety circuitry.

5-14.10.1 A time delay shall be permitted that allows the operator to take corrective action, provided an alarm is activated and it can be proved to the authority having jurisdiction that such a delay cannot create a hazard.

5-14.10.2 Coolant piping systems shall be protected from freezing and overpressurization.

5-15 Ignition of Main Burners — Fuel Gas or Oil.

5-15.1 If a reduced firing rate is required for safe and reliable ignition of the burner (forced low-fire start), an interlock shall be provided to prove the control valve is properly positioned prior to each attempt at ignition.

5-15.2 Electrical ignition energy for direct spark ignition systems shall be terminated after the main burner trial-for-ignition period.

Exception: Continuous operation of direct spark igniters shall be permitted for radiant tube–type heating systems that do not require combustion safeguards.

5-16* Excess Temperature Limit Controller.

5-16.1 An excess temperature limit controller shall be provided and interlocked into the combustion safety circuitry, unless it can be demonstrated that a safe temperature limit cannot be exceeded.

5-16.2 Operation of the excess temperature limit controller shall cut off the source of heat before the safe temperature is exceeded.

5-16.3 Operation of the excess temperature limit controller shall require manual reset before restart of the furnace or affected furnace zone.

5-16.4 Failure of the temperature-sensing element of the excess temperature limit controller shall cause the same response as an excess temperature condition.

CAUTION

Where a thermocouple is used with an excess temperature limit controller, ruggedly constructed and conservatively rated thermocouples and extension wires shall be used to minimize the probability of a short circuit in the thermocouple or thermocouple extension wires. Thermocouple short circuits should not result in the action required by 5-16.4.

5-16.5 The temperature-sensing element of the excess temperature limit controller shall be suitable for the temperature and atmosphere to which it is exposed.

5-16.6 The temperature-sensing element of the excess temperature limit controller shall be located to sense the temperature most critical to safe operation.

5-16.7 The excess temperature limit controller set point shall be displayed or clearly marked in units of temperature (°F or °C).

5-16.8 The operating temperature controller and its temperature-sensing element shall not be used as the excess temperature limit controller.

5-17 1400°F (760°C) Bypass Controller.

5-17.1 Where permitted in accordance with 5-9.1 to switch the flame supervision out of the combustion safety circuitry or to bring unsupervised burners on-line, a 1400°F (760°C) bypass controller shall be used.

5-17.2 Failure of the temperature-sensing element shall cause the same response as an operating temperature less than 1400°F (760°C).

5-17.3 The temperature-sensing element of the 1400°F (760°C) bypass controller shall be suitable for the temperature and atmosphere to which it is exposed.

5-17.4 The temperature-sensing element of the 1400°F (760°C) bypass controller shall be located to sense the temperature most critical to safe operation.

5-17.5 The 1400°F (760°C) bypass controller set point shall not be set below 1400°F (760°C), and the set point shall be displayed or clearly marked in units of temperature (°F or °C).

5-17.6 Visual indication shall be provided to indicate when the 1400°F (760°C) bypass controller is in the bypass mode.

5-17.7 The operating temperature controller and its temperature-sensing element shall not be used as the 1400°F (760°C) bypass controller.

5-18 Electrical Heating Systems.

5-18.1 Heating Equipment Controls.

5-18.1.1* Electric heating equipment shall be equipped with a main disconnect device or with multiple devices to provide back-up circuit protection to equipment and to persons servicing the equipment. Such a disconnecting device(s) shall be made capable of interrupting maximum available fault current as well as rated load current. *(See NFPA 70, National Electrical Code.)*

5-18.1.2 Shutdown of the heating power source shall not inadvertently affect the operation of equipment such as conveyors, ventilation or recirculation fans, cooling components, and other auxiliary equipment.

5-18.1.3 Branch Circuits. Branch circuits and branch circuit protection for all electrical circuits in the furnace heating system shall be provided in accordance with NFPA 70, *National Electrical Code*, and with NFPA 79, *Electrical Standard for Industrial Machinery.*

Exception: The requirements for resistance heaters larger than 48 amperes to be broken down into subdivided circuits not to exceed 48 amperes shall not apply to industrial ovens and furnaces.

5-18.1.4* The capacity of all electrical devices used to control energy for the heating load shall be selected on the basis of continuous duty load ratings where fully equipped for the location and type of service proposed.

5-18.1.5 All controls using thermal protection or trip mechanisms shall be located or protected to preclude faulty operation due to ambient temperatures.

5-18.2* Excess Temperature Limit Controller.

5-18.2.1 An excess temperature limit controller shall be provided and interlocked into the heating control circuitry.

Exception: Where it can be demonstrated that a safe temperature limit cannot be exceeded.

5-18.2.2 Operation of the excess temperature limit controller shall cut off the source of heat before the safe temperature is exceeded.

5-18.2.3 Operation of the excess temperature limit controller shall require manual reset before restart of the furnace or affected furnace zone.

5-18.2.4 Failure of the temperature-sensing element of the excess temperature limit controller shall cause the same response as an excess temperature condition.

CAUTION

Where a thermocouple is used with an excess temperature limit controller, ruggedly constructed and conservatively rated thermocouples and extension wires shall be used to minimize the probability of a short circuit in the thermocouple or thermocouple extension wires. Thermocouple short circuits should not result in the action required by 5-18.2.4.

5-18.2.5 The temperature-sensing element of the excess temperature limit controller shall be suitable for the temperature and atmosphere to which it is exposed.

5-18.2.6 The temperature-sensing element of the excess temperature limit controller shall be located to sense the temperature most critical to safe operation.

5-18.2.7 The excess temperature limit controller set point shall be displayed or clearly marked in units of temperature (°F or °C).

5-18.2.8 The operating temperature controller and its temperature-sensing element shall not be used as the excess temperature limit controller.

5-19* Fluid-Heated Systems — Excess Temperature Limit Controller.

5-19.1 Where a fluid-heated system can cause an excess temperature condition within the oven served, an excess temperature limit controller shall be provided and interlocked to interrupt the supply of heat transfer fluid to the oven.

5-19.2* Interrupting the supply of heat transfer fluid to an oven shall not cause an unsafe condition to the remainder of the heat transfer system.

5-19.3 Operation of the excess temperature limit controller shall cut off the source of heat before the safe temperature is exceeded.

5-19.4 Operation of the excess temperature limit controller shall require manual reset before re-establishing the flow of heat transfer fluid.

5-19.5 Failure of the temperature-sensing element of the excess temperature limit controller shall cause the same response as an excess temperature condition.

CAUTION

Where a thermocouple is used with an excess temperature limit controller, ruggedly constructed and conservatively rated thermocouples and extension wires shall be used to minimize the probability of a short circuit in the thermocouple or thermocouple extension wires.

5-19.6 The temperature-sensing element of the excess temperature limit controller shall be suitable for the temperature and atmosphere to which it is exposed.

5-19.7 The temperature-sensing element of the excess temperature limit controller shall be located to sense the temperature most critical to safe operation.

5-19.8 The excess temperature limit controller set point shall be displayed or clearly marked in units of temperature (°F or °C).

5-19.9 The operating temperature controller and its temperature-sensing element shall not be used as the excess temperature limit controller.

5-20 Vacuum Furnace Systems.

5-20.1 Pressure controls shall be installed on all Class D vacuum furnaces to prevent excessively high pressures beyond the inherent design of the vacuum vessel. These controls are designed to prevent damage due to excessive pressures, damage due to oxidation of internal equipment materials, and harm to the safety of the furnace operator.

5-20.2* Indicating or recording vacuum gauges shall be employed to measure pressures in the vessel chamber and in the piping between the rough valve and the vacuum pump(s). Gauges shall have the capability to measure the expected lowest pressure achievable by the vacuum system.

5-20.3 The vacuum chamber (and the cooling or quench vestibule, if separate) shall be equipped with a pressure-relief valve that protects the chamber, attachments, and doors from excessive gas pressure during the pressurizing or cooling cycles.

5-20.4 Automatic valves shall be provided to close the holding pump, foreline, roughing, and main vacuum valves in the event of the failure of a power supply or other valve-actuating medium in order to prevent pump oil or air from passing through the system or causing damage to the furnace or load.

5-20.5 Valves or pilot operators for valves whose inadvertent actuation could result in a hazardous condition shall have any manual actuation feature protected against unauthorized operation.

5-20.6 A warning label shall be permanently affixed to diffusion pumps covering safe methods of servicing pumps that reads as follows: "Do not open oil drain or fill plugs for service until pump heater is at room temperature. Otherwise, ignition of pump oil can occur with rapid expansion of gas causing damage to the pump and furnace hot zone."

5-21 Internal Quench Vacuum Furnaces.

5-21.1 Wherever a vacuum furnace has an internal liquid quench chamber, in addition to the above safety controls, the controls specified in this section shall be provided.

5-21.2 Automatic temperature controls shall be installed in pressure-type water-cooling and oil-cooling systems to ensure the desired jacket temperature.

5-21.3 Wherever an external door adjacent to the quench chamber is employed, the operation of such door shall be interlocked so that it cannot be opened unless the elevator is in its full loading or quenching position.

Exception: A manual override shall be permitted to be used in emergencies.

5-21.4 Controls for the admittance and maintenance of special atmosphere within the quench chamber shall conform to the controls described in Section 8-2.

5-21.5 The quench reservoir shall be equipped with a reliable quench medium level indicator. If of the sight glass type, the level indicator shall be of heavy-duty construction and protected from mechanical damage.

5-21.6 Where the furnace arrangement dictates, a limit switch shall be interlocked into the load transfer system to prevent transfer of the load in the heat chamber to the quench rack unless the quench rack is in proper position.

5-21.7 The quench tank shall be equipped with a low liquid level device arranged to sound an alarm, prevent the start of quenching, and shut off the heating medium in case of a low liquid level condition.

5-21.8 Excess temperature limit control shall be provided and interlocked to shut off the quench heating medium automatically and shall require operator attention in case of excessive quench medium temperature. Excess temperature limit control shall be interlocked to prevent the start of quenching in case of excessive quench medium temperature. Audible and visual alarms shall be provided.

5-21.9 Where agitation of the quench medium is required to prevent overheating, the agitation shall be interlocked to prevent quenching until the agitator has been started.

5-21.10 A reliable means shall be used to sample for water in quench oil.

Chapter 6 Fume Incinerators

6-1 General.

6-1.1* The design and construction of fume incinerators shall comply with all requirements of Class A ovens in NFPA 86, *Standard for Ovens and Furnaces.*

Exception: The requirements for explosion relief shall not apply to fume incinerators.

6-1.2 Special precautions shall be taken to reduce the fire hazards where the relative location of equipment or the type of fumes generated are such that combustible liquids can condense or solids can be deposited between the generating process and the afterburner. *(See Chapters 3 and 12.)*

6-2* Direct-Fired Fume Incinerators.

6-2.1* The design and operation of combustion systems and controls shall comply with all parts of this standard pertaining to direct-fired ovens.

6-2.2* An excess temperature limit controller shall be provided to prevent the uncontrolled temperature rise in the fume incinerator. Operation of the excess temperature limit controller shall interrupt fuel to the fume incinerator burner and shall interrupt the source of fumes to the incinerator.

6-3 Direct Heat Recovery Systems.

6-3.1 An adequate supply of proven fresh air shall be introduced into the system to provide the oxygen necessary for combustion of hydrocarbons as well as primary burner fuel. Fresh air shall be introduced through openings that supply air directly to each zone circulating system.

6-3.2 Where direct heat recovery systems are employed and portions of the incinerator exhaust gases are utilized as the heat source for one or more of the zones of the fume-generating oven, special precautions shall be taken to prevent recycling unburned solvent vapors.

6-4* Catalytic Fume Incinerators.

6-4.1 The requirements in Section 6-2 for direct-fired fume incinerators shall apply to catalytic fume incinerators.

6-4.2* An additional excess temperature limit controller shall be located downstream from the discharge of the catalyst bed for thermal protection of the catalyst elements. Operation of the excess temperature limit controller shall interrupt fuel to the burner and shall interrupt the source of fumes.

6-4.3* Sufficient process exhaust ventilation shall be provided to maintain vapor concentrations that cannot generate temperatures at which thermal degradation of the catalyst can occur.

6-4.4* A differential pressure (ΔP) high limit switch, measuring across the catalyst bed, shall be used to detect particulate contamination. Operation of the high limit differential pressure switch shall interrupt fuel to the fume incinerator burner and shall interrupt the source of fumes to the incinerator.

6-4.5* Where catalysts are utilized with direct heat recovery, a maintenance program shall be established, and frequent tests of catalyst performance shall be conducted so that unburned or partially burned vapors are not reintroduced into the process oven.

Chapter 7 Integral Liquid Quench Vacuum Furnaces

7-1* General Requirements.

7-1.1 The vacuum chamber or quench vestibule, or both, shall be equipped with a pressure-relief valve that protects against excessive pressure during the backfilling portion of the cycle.

7-1.2 The cooling medium shall maintain the quench vestibule interior at a temperature that prevents condensation.

7-1.3 Where quench vestibules are used with semicontinuous furnaces, the quench vestibule shall be vacuumtight and shall be constructed of noncombustible materials.

7-1.4 If an intermediate door between the furnace and the quench vestibule is employed, it shall be closed during the quenching operation to serve as a radiation baffle. If the door does not close, an alarm shall be used to notify the operator.

7-2 Construction of Quenching Tanks.

7-2.1 The quench tank shall be designed and constructed to contain the quench medium capacity at the expected operating temperature and with maximum work load volume.

7-2.1.1 Where the elevator and work load are submerged, the quench tank shall be designed and operated with a maximum quench medium level of not less than 6 in. (152 mm) below the door or any opening into the furnace.

7-2.1.2 The quench tank shall be designed for a minimum quench medium capacity, without the operation of the cooling system, to quench a maximum gross load such that the maximum quenching medium temperature is at least 50°F (28°C) below its flash point.

7-2.2* Base materials, weld filler materials, and welding procedures used for the tank fabrication shall be selected to provide resistance to corrosion by the cooling medium.

7-3 Elevators.

7-3.1 The elevator shall be designed to immerse the work charge in the quench medium with minimum splashing. At termination of the timed quench cycle, the elevator shall be raised to the drain position at hearth level.

7-3.2 The elevator and elevating mechanism shall be designed to handle the maximum rated loads.

7-3.3 Elevator guides shall be provided to ensure uniform stabilized movement of the elevator.

7-3.4 Tray guides or stops shall be provided to ensure that the tray is in position on the elevator.

7-4 Cooling Systems.

7-4.1* The cooling system shall be capable of maintaining the quench medium temperature within operating range at minimum quench intervals at maximum gross loads.

7-4.2 Heat Exchanger within Quench Tank.

7-4.2.1 The heat exchanger shall be constructed of materials that cannot be corroded by either cooling medium or quench medium.

7-4.2.2 The heat exchanger shall be subjected to a minimum pressure test of 150 percent of the maximum designed working pressure after installation in a quench tank.

7-4.2.3 The heat exchanger shall be located within the quench tank so as to prevent mechanical damage by the elevator or the load to be quenched.

7-4.2.4 The cooling medium flow shall be controlled by an automatic temperature controller.

7-4.2.5 A pressure-relief device shall be provided to protect the heat exchanger. Relief shall be piped to a safe location.

7-4.2.6 Water shall not be used as a cooling medium within a quench tank that uses a combustible liquid quench medium.

7-4.3 External Liquid-Cooled Heat Exchanger.

7-4.3.1 Heat exchanger tubes that are exposed to water shall be constructed of corrosion-resistant materials.

7-4.3.2 After fabrication, the heat exchanger shall be subjected to a minimum pressure test of 150 percent of the maximum designed working pressure.

7-4.3.3 The pressure of the quench medium through the heat exchanger shall be greater than the coolant pressure applied. A differential pressure switch shall be required and interlocked with the quench cycle.

7-4.3.4 A pressure-relief device shall be provided to protect the heat exchanger. Relief shall be piped to a safe location.

7-4.4 External Air-Cooled Heat Exchanger System.

7-4.4.1 External air-cooled heat exchangers installed outdoors shall be designed and installed to withstand anticipated wind forces.

7-4.4.2 External air-cooled heat exchangers that are installed outdoors or that utilize supplemental water-cooling shall be constructed of materials that are able to withstand corrosion.

7-4.4.3 An external heat exchanger installed outdoors shall be provided with lightning protection if located in an exposed, rooftop location.

7-4.4.4 If the air-cooled heat exchanger is installed in a rooftop location, it shall be installed in a curbed or diked area and drained to a safe location outside of the building.

7-5 Electric Immersion Heaters.

7-5.1 Electric immersion heaters shall be of sheath-type construction.

7-5.2 Heaters shall be installed so that the hot sheath is fully submerged in the quench medium at all times.

7-5.3 The quench medium shall be supervised by a temperature controller arranged to maintain the quench medium within the operating temperature range.

7-5.4 The electrical heating system shall be interlocked with the quench medium agitation or recirculation system to prevent localized overheating of the quench medium.

Chapter 8 Vacuum Furnaces Used With Special Flammable Atmospheres

8-1 General.

8-1.1* Scope. Chapter 8 shall apply to any vacuum chamber or vacuum furnace in which a flammable gas is used at a pressure of one-half or more of its lower explosive limit (LEL) in air.

8-1.2* Flammable Gases. Flammable gases shall be permitted to be used in conjunction with vacuum furnaces for thermal processes such as carburizing, nitriding, brazing, sintering, and chemical vapor deposition.

8-2 Safety Controls and Equipment.

8-2.1 A minimum supply of inert purge gas equal to five times the total vacuum system volume shall be provided at all times.

8-2.2 The purge gas supply shall be connected to the vacuum chamber through a normally open valve. A pressure sensor shall monitor the purge gas line pressure and shall stop the supply of flammable gas if the pressure becomes too low to allow purging in accordance with 8-2.1. Any manual inert purge gas shutoff valves shall be proven open through the use of a position monitoring switch and interlocked to prevent the introduction of flammable gas.

8-2.3 Flammable Gas Supply.

8-2.3.1 The flammable gas supply shall be connected to the vacuum chamber through a normally closed automatic safety shutoff valve.

8-2.3.2 For vacuum furnaces that rely on a partial vacuum to hold the door closed, the flammable gas supply shall be connected to the vacuum chamber through two normally closed automatic safety shutoff valves.

8-2.3.3 A manual shutoff valve shall be provided in any flammable atmosphere supply pipe.

8-2.4 The gas supply system shall be interlocked with the vacuum system to prevent the introduction of any flammable atmosphere until the furnace has been evacuated to a level of 1×10^{-1} torr (13.3 Pa) or less.

8-2.5 High and low pressure switches shall monitor the flammable gas line pressure and shall be interlocked to shut off the supply of gas when its pressure deviates from the design operating range.

8-2.6* In the case of a multiple chamber–type or continuous-type vacuum furnace, each chamber shall be regarded as a separate system. Interlocks shall be provided that prevent the valves from opening between adjacent interconnecting chambers once a flammable atmosphere has been introduced into any of them.

8-2.7 The vacuum pumping system shall be interlocked with the supply gas system so that mechanical pumps continue to operate while flammable gas is in the vacuum chamber, to prevent air from backstreaming through nonoperating pumps.

8-2.8 Mechanical pump gas ballast valves shall be piped to a source of inert gas. Vacuum air release valves on roughing or forelines shall be piped to a source of inert gas.

8-2.9 Manual air release valves shall not be permitted.

8-2.10 Vacuum furnaces that rely on a partial vacuum to hold the door closed shall incorporate a pressure switch, independent from the chamber pressure control device, to terminate flammable gas addition before the backfill pressure rises to a point where door clamping is lost.

8-2.11 Vacuum furnaces that are backfilled with flammable gases to pressures greater than that required to hold the door closed shall incorporate clamps and seals to ensure the door is tightly and positively sealed.

8-2.12* Sight glasses shall be removed or valved off during operation with flammable gases. This requirement shall not apply to sight glasses used solely for pyrometers.

8-3 Flammable Gases.

8-3.1 During processing, flammable gases shall be exhausted from vacuum furnaces by pumping them through the vacuum pumps or by venting in continuous flow to the atmosphere.

8-3.2 If the flammable gas is exhausted through a vacuum pump, the system shall be designed to prevent air backflow through the pump if it stops.

8-3.3 Venting of the vacuum pump shall be in accordance with 3-4.4. The pump discharge shall be permitted to be diluted with air or inert gas to lower the combustible level of the mixture below the LEL, or the discharge shall be permitted to be passed through a burner.

8-3.4 If the flammable gas is vented to the atmosphere directly without passing through the vacuum pumps, the vent line shall be provided with a positive means of preventing air from entering the furnace chamber.

8-3.5 If the flammable gas is vented to the atmosphere through a burner, the vent line shall be provided with a positive means of preventing air from entering the furnace chamber. The existence of the burner ignition source shall be monitored independently, with interlocks to shut off the flammable gas supply and initiate inert gas purge if the flame is not sensed.

8-3.6 In applications where flammable gas is used to maintain chamber pressure above atmospheric pressure, a pressure switch shall be interlocked to close the flammable gas supply if the chamber pressure exceeds the maximum operating pressure. The pressure switch shall be independent from the chamber pressure control device.

8-3.7 In applications where flammable gas is used to maintain chamber pressure above atmospheric pressure, a pressure switch shall be interlocked to close the flammable gas supply and initiate purge if the chamber pressure drops below the minimum operating pressure.

8-3.8 Where flammable gas is exhausted through a vent (not through the pump), the vent valve shall not open until a pressure above atmosphere is attained in the chamber.

8-4 Removal of Flammable Gas.

8-4.1 Purging with Inert Gas.

8-4.1.1 When an inert purge is initiated, the flammable gas valve shall be closed.

8-4.1.2 Purging shall be complete when two consecutive analyses of the vent gas from the furnace indicate that less than 50 percent of the LEL has been reached. Alternatively, purge shall be complete after five furnace volume changes have occurred.

8-4.2 Purging with Vacuum. As an alternate procedure to inert gas purging for the removal of the flammable gas atmosphere, the furnace shall be pumped down to a minimum vacuum level of 1×10^{-1} torr (13.3 Pa) prior to inert gas backfill.

8-5* Emergency Shutdown Procedure. In the event of an electrical power failure or flammable gas failure, the system shall be purged in accordance with 8-4.1.

Chapter 9 Bulk Atmosphere Gas Storage Systems

9-1 Construction.

9-1.1* All storage tanks and cylinders shall comply with local, state, and federal codes relating to pressures and type of gas.

9-1.2 Vessels, controls, and piping shall be constructed to maintain their integrity under maximum design pressures and temperatures.

9-2* Storage Systems. Storage systems shall comply with the following NFPA standards:

(1) Liquefied petroleum gas systems shall be in accordance with NFPA 58, *Liquefied Petroleum Gas Code.*
(2) Gas piping shall be in accordance with NFPA 54, *National Fuel Gas Code.*
(3) Hydrogen storage systems shall be in accordance with NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites.*
(4) Oxygen storage systems shall be in accordance with NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites.*
(5) Processing atmosphere gas storage systems not covered by an NFPA standard (e.g., anhydrous ammonia) shall be installed in accordance with recommendations from the supplier and all applicable local, state, and federal codes.

Chapter 10 Vacuum Induction Furnaces

10-1* Scope. Chapter 10 shall apply to furnaces that use induction heating and a vacuum atmosphere. These include furnaces used for melting, casting, sintering, hot pressing, outgassing, degassing, metal purification, general heat treating, brazing, and chemical vapor deposition.

10-2 Construction.

10-2.1 The furnace chamber design shall take into account the heating effect of the induction field and shall be sized and constructed of materials to minimize the heating effect on the walls.

10-2.2* Where water is used as a cooling medium, the main water control valve shall remain open in the event of a power failure so that cooling water continues to flow to the furnace.

10-2.3 Wherever a coil or coils having multiple sections or multiple water pads are used, such coils or pads shall have separately valved water circuits to ensure continuity of cooling in the event of a water leak.

10-2.4 Water-cooled induction leads shall be designed to minimize any work-hardening as a result of movement.

10-2.5 Wherever an elevator is used, the elevating mechanism shall be designed to handle the maximum loads. Elevator guides shall be provided to ensure uniform stabilized movement. The elevator mechanism shall be shielded from spillage of molten metal.

10-3* Heating Systems.

10-3.1 For the purpose of Chapter 10, the term *heating system* shall include an electrical power supply, induction coil, and related hardware.

10-3.2 All components, such as the vacuum chamber, power supply, and control cabinet, shall be grounded.

Exception: Induction coils shall not be required to be grounded.

10-3.3* The geometry of the coil and its placement with respect to the susceptor or load shall be designed for the heating rate, operating temperature, and temperature uniformity specification required for the process.

10-3.4* The electrically energized induction coil shall be supported so that it does not come into contact with the susceptor or work pieces or fixtures and so that it avoids contact with other internal furnace components.

10-3.5 The electrical insulation of the induction coil supports or coil separators shall withstand exposure to specified temperature, vacuum levels, and operating voltage and frequency.

10-3.6 In the case of an insulated or individually wrapped induction coil, the requirement of 10-3.5 also shall apply to the tape or insulation.

10-3.7* Power terminal connection points to power supply cables shall be covered or housed to prevent electrical hazard to personnel.

10-3.8 The choice and sizing of the thermal insulation shall be determined by operating temperature, vacuum level, and other operating criteria, such as compatibility with the process.

10-4 Safety Controls.

10-4.1 All electrical safety controls and protective devices required for induction systems in NFPA 70, *National Electrical Code*, shall apply.

10-4.2 An interlock shall be provided to disconnect power to the furnace wherever opening the control cabinet door exposes persons to contact with hazardous voltages.

10-4.3 Where an open system is used, an open sight drain in the water coolant shall be provided for immediate, visible indication of waterflow in the cooling line of the induction coil.

10-4.4 The flow of the cooling water shall be monitored at the discharge of each induction coil circuit to shut down the power in the event of inadequate flow.

10-4.5* Temperature sensors at the outlet of the cooling system shall be furnished with contact switches to shut down the heating power in the event that the temperature of the cooling water is beyond the recommended temperature of operation, as specified by the design of the equipment.

10-4.6 A molten metal leak detector shall be installed on all vacuum induction melting furnaces where the capacity for melting is more than 500 lb (227 kg) of metal. This detector shall sound an alarm indicating a leaking crucible whenever it senses molten metal in the refractory surrounding the crucible.

10-4.7 A ground-fault detection device shall be provided and installed on the induction coil itself to sound an alarm and shut off power in the event of a ground-fault.

10-4.8 Wherever an elevator is used in a vacuum induction melting furnace, the external door operation shall be interlocked so that it cannot be opened unless the elevator is in position.

10-4.9 Also, where such an elevator is used, the crucible shall be interlocked so that it cannot be in the pour position unless the elevator is in position.

Chapter 11 Inspection, Testing, and Maintenance

11-1* Responsibility of the Manufacturer and the User. The equipment manufacturer shall inform the user regarding the need for operational checks and maintenance and shall provide complete and clear inspection, testing, and maintenance instructions. The final responsibility for establishing an inspection, testing, and maintenance program that ensures that the equipment is in proper working order shall be that of the user.

11-2* Checklist. The user's operational and maintenance program shall include all procedures that apply to the specific equipment. An operational and maintenance checklist shall be maintained.

Chapter 12 Fire Protection

12-1* General. Furnaces can present fire hazards to the surrounding area in which they are installed. Fixed fire extinguishing systems shall be provided to protect against such hazards as overheating, spillage of molten salts or metals, quench tanks, ignition of hydraulic oil, and escape of fuel. It shall be the user's responsibility to consult with the authority having jurisdiction concerning the necessary requirements for such protection.

CAUTION

Personnel shall be cautioned that hydrogen flames are invisible.

12-2 Sprinkler and Spray Systems. Subject to the authority having jurisdiction, either automatic sprinkler or water spray systems shall be provided.

12-2.1 Automatic Sprinkler Systems. Automatic sprinkler installations shall be in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

12-2.2 Water Spray Systems. Water spray systems shall be fixed systems and automatic in operation and shall be in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection.*

12-3 Portable Protection Equipment.

12-3.1 Extinguishers. Approved portable extinguishing equipment shall be provided for the furnace and related equipment. Such installations shall be in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.*

12-3.2 Inside Hose Connections. Where small hose streams are required, they shall be installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, or NFPA 14, *Standard for the Installation of Standpipe and Hose Systems.*

Chapter 13 Referenced Publications

13-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix G.

13-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 1998 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1999 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 1996 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 1996 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 1997 edition.

NFPA 50, *Standard for Bulk Oxygen Systems at Consumer Sites*, 1996 edition.

NFPA 50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*, 1999 edition.

NFPA 54, *National Fuel Gas Code*, 1999 edition.

NFPA 58, *Liquefied Petroleum Gas Code*, 1998 edition.

NFPA 70, *National Electrical Code®*, 1999 edition.

NFPA 79, *Electrical Standard for Industrial Machinery*, 1997 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1999 edition.

NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, 1999 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, 1999 edition.

13-1.2 Other Publications.

13-1.2.1 ANSI Publication. American National Standards Institute, Inc., 11 West 42nd Street, 13th floor, New York, NY 10036.

ANSI A14.3, *Safety Requirements for Fixed Ladders*, 1992.

13-1.2.2 ASME Publications. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*, 1998.
ASME B31.1, *Power Piping*, 1995.
ASME B31.3, *Process Piping*, 1996.

13-1.2.3 ASTM Publication. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 396, *Standard Specifications for Fuel Oils*, 1998.

13-1.2.4 U.S. Government Publication. U.S. Government Printing Office, Washington, DC 20402.

Code of Federal Regulations, Title 29, Parts 1910.24 through 1910.29, 1998.

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-1-1.2 Vacuum furnaces generally are described as either cold-wall furnaces, hot-wall furnaces, or furnaces used for casting or melting of metal at high temperatures up to 5000°F (2760°C). There can be other special types.

For more detailed information on the various types of furnaces, reference should be made to Table A-1-1.2.

Table A-1-1.2 Vacuum Furnace Protection

Operating and Subject Safety Devices	Cold Wall			Hot Wall		Casting and Melting			
	Induction	Resistance	Electron Beam	Gas-Fired	Electric	Induction	Electron Beam	Electric Arc	Plasma Arc
A. Vacuum System	yes	yes	yes	yes	yes	yes	yes	yes	yes
Vacuum chamber	yes	yes	yes	yes	yes	yes	yes	yes	yes
Roughing pump	yes	yes	yes	yes	yes	yes	yes	yes	yes
Diffusion pump	op	op	yes	op	op	op	yes	op	no
Holding pump	op	op	op	op	op	op	op	op	no
Retort	no	no	no	yes	yes	no	no	no	no
Multichamber	op	op	op	op	op	op	op	op	op
Internal fan (temp. uniformity)	no	op	no	op	op	no	no	no	no
B. Heating System	yes	yes	yes	yes	yes	yes	yes	yes	yes
High voltage	no	no	yes	no	no	no	yes	yes	yes
High current	yes	yes	no	no	yes	yes	yes	yes	yes
C. Cooling System									
Work cooling	yes	yes	yes	op	op	op	op	no	yes
Gas quench	op	op	op	op	op	op	op	no	no
Oil quench	op	op	no	no	no	no	no	no	no
Water quench	op	op	no	no	no	no	op	no	no
Fans, blower	op	op	op	op	op	op	op	no	op
Port-bungs	op	op	op	op	op	no	no	no	op
External–internal heat exchanger	op	op	op	op	op	op	op	op	op
Water-cooling equipment	yes	yes	yes	yes	yes	yes	yes	yes	yes
D. Process Atmosphere Cycle									
Hydrogen	op	op	no	op	op	no	no	no	op
Nitrogen	op	op	no	op	op	no	no	no	op

Table A-1-1.2 Vacuum Furnace Protection ***(Continued)***

Operating and Subject Safety Devices	Cold Wall			Hot Wall		Casting and Melting			
	Induction	Resistance	Electron Beam	Gas-Fired	Electric	Induction	Electron Beam	Electric Arc	Plasma Arc
Methane	op	op	no	op	op	no	no	no	op
Argon	op	op	no	op	op	no	no	no	yes
Helium	op	op	no	op	op	no	no	no	op
E. Material Handling									
Internal	yes	yes	yes	yes	yes	yes	yes	yes	yes
External	yes	yes	yes	yes	yes	yes	yes	yes	yes
F. Instrument Controls									
Temperature	yes	yes	yes	yes	yes	yes	yes	yes	yes
Vacuum	yes	yes	yes	yes	yes	yes	yes	yes	yes
Pressure	yes	yes	yes	yes	yes	yes	yes	yes	yes
Flow	yes	yes	yes	yes	yes	yes	yes	yes	yes
Electrical	yes	yes	yes	yes	yes	yes	yes	yes	yes
G. Hazards of Heating System				[Refer to NFPA 86 & 86C]					
Gas-fired	no	no	no	yes	no	no	no	no	no
Electric heated	yes	yes	yes	no	yes	yes	yes	yes	yes
Cooling water to be circulating	yes	yes	yes	yes	yes	yes	yes	yes	yes
Overheating	yes	yes	yes	yes	yes	yes	yes	yes	yes
Steam buildup	yes	yes	yes	yes	yes	yes	yes	yes	yes
Diffusion pump element	yes	yes	yes	yes	yes	op	yes	op	no
Pump element overheating	yes	yes	yes	yes	yes	op	yes	op	no
Accumulation of air	yes	yes	yes	yes	yes	yes	yes	yes	yes
Hydrogen accumulation	op	op	op	op	op	no	no	no	no
Other combustibles	no	no	no	no	no	no	no	no	no
Water in oil explosion	no	yes	no	no	yes	no	no	no	no
Radiation	no	no	yes	no	no	no	yes	yes	yes
Water sentinel	yes	yes	yes	yes	yes	yes	yes	yes	yes
Electrical short safety shutdown	yes	yes	yes	—	yes	yes	yes	yes	yes
H. Personnel Safety Hazards	yes	yes	yes	yes	yes	yes	yes	yes	yes

Notes:
1. yes — Equipment is provided or condition is present
2. op — Optional, and there might be a choice

Figures A-1-1.2(a) and (b) show two examples of different types of cold-wall vacuum furnaces. Figure A-1-1.2(c) shows an example of a hot-wall vacuum furnace.

Figure A-1-1.2(a) Example of cold-wall, horizontal, front-loading vacuum furnace.

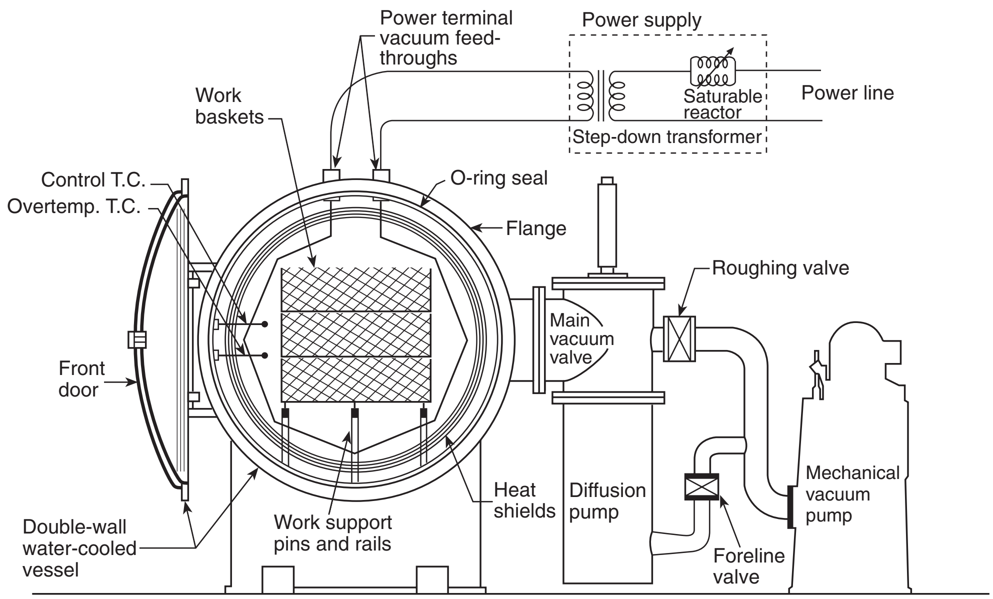


Figure A-1-1.2(b) Example of cold-wall, induction-heated vacuum furnace.

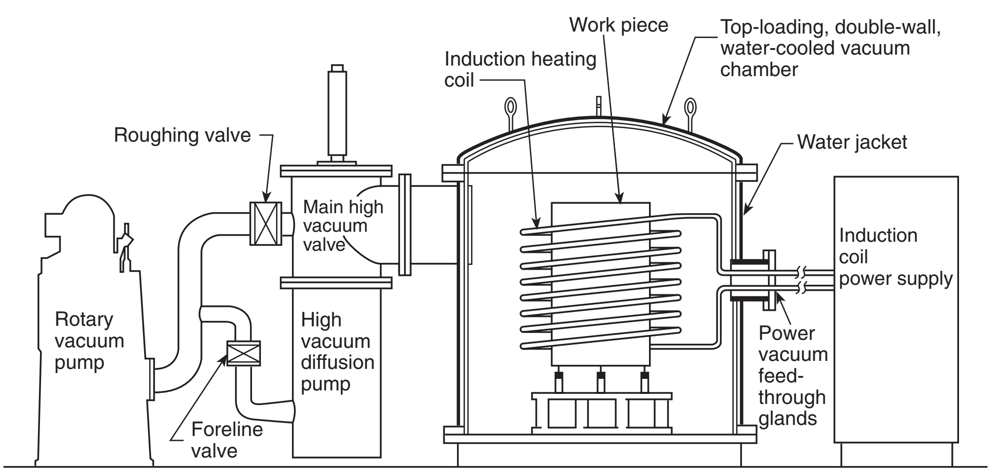
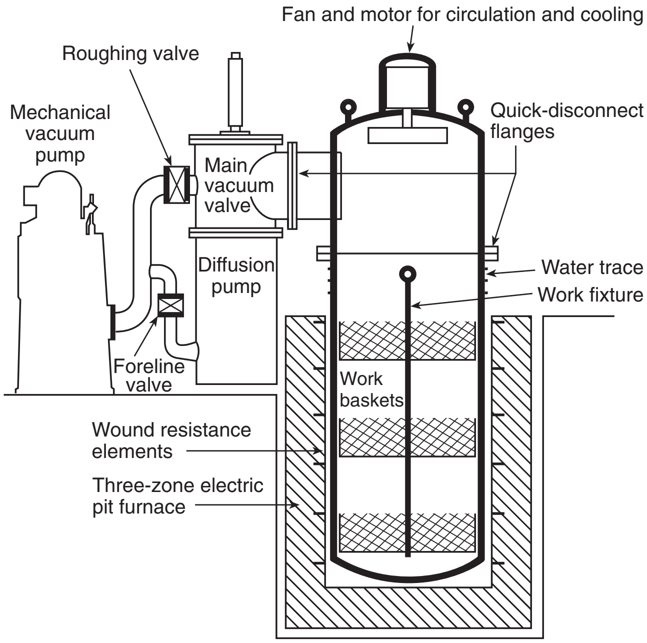


Figure A-1-1.2(c) Example of hot-wall, single-pumped, retort vacuum furnace.



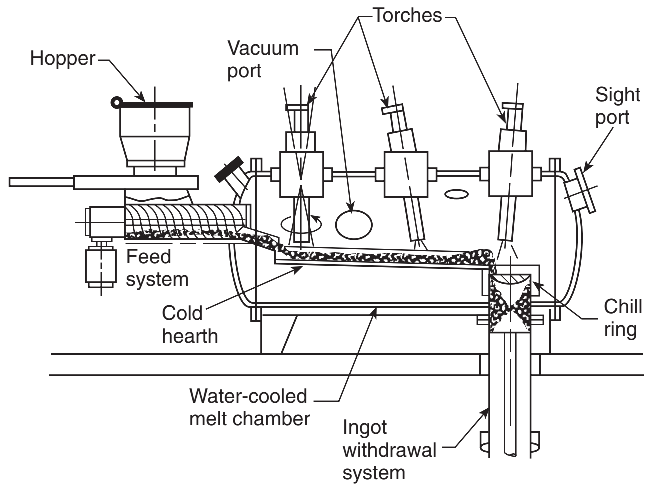
Plasma Melting. Plasma melting is a process by which metal solids, powders, chips, and fines can be consolidated into ingot or slab form. Melting is accomplished by use of an ionized gas that transfers heat from the plasma torch to the material. The gas might be oxidizing, reducing, or inert, depending on the process requirements. The temperature of the plasma gas is in excess of 20,000°C (36,032°F). Material consolidation might be in the form of an ingot, usually extracted from the bottom of the melt chamber, or a slab that is removed horizontally from the melt chamber.

The melt chamber operating pressure might be varied from 10^{-2} atmospheres to 2 atmospheres, making the process suitable for a wide variety of metals and alloys. Cleaning and refinement of the material might be accomplished by the use of hearth melting, stirring action by torch manipulation, inductive stirring coils, or vacuum/pressure cycling of the melt chamber.

The melt chamber, torches, copper hearths, consolidation containment system, and power supplies are water-cooled. Each water-cooled circuit is monitored for low flow and high temperature with alarms for all circuits and power disruption for critical circuits, or both.

Solid-state power supplies are utilized to provide power to the torches, which range in size from 50 kW for a small research unit to multiple torches of 1000 kW each for large production melters. The torches provide *x*, *y*, and *z* movements that are programmable or computer controlled. *[See Figure A-1-1.2(d).]*

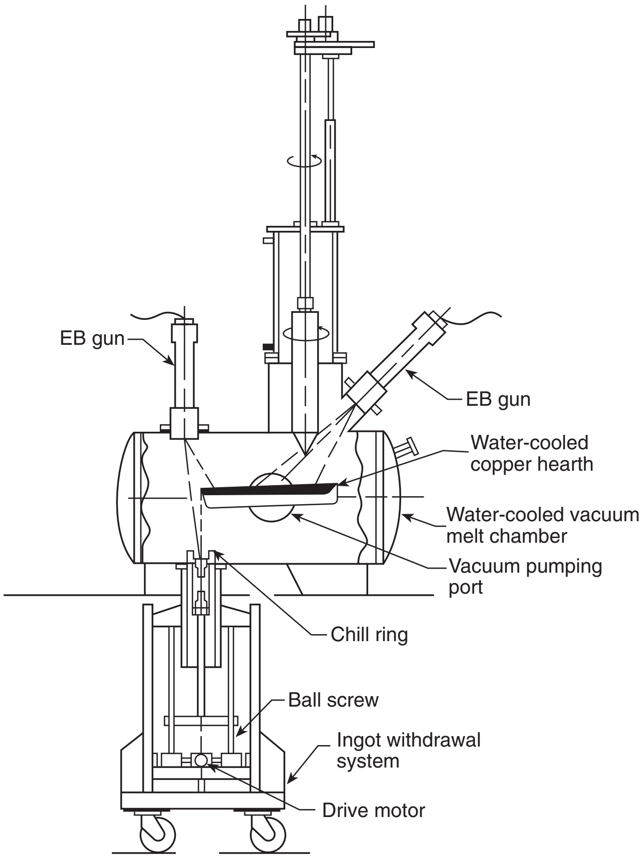
Figure A-1-1.2(d) Example of three-torch production plasma melter.



Electron-Beam (EB) Melter. Of all commercial melting techniques, electron-beam (EB) melting is capable of producing the highest refinement of end product. The beam of the electron gun can be focused to produce heat intense enough to vaporize even those metals with the highest melting points. Where combined with a vacuum atmosphere of approximately 10^{-4} torr (1.3×10^{-6} Pa), most impurities can be separated from the product being melted. EB melting is especially suited for refining refractory metals and highly reactive metals, but it also has applications in melting alloy steels.

Commercial EB melters are available in a variety of sizes and configurations. Figure A-1-1.2(e) illustrates a vertical feed system that allows the molten metal to drop from the feed stock into a water-cooled copper retention hearth, where the molten metal is further refined by the oscillating beams of the two guns. The retention time of the metal in the hearth is controlled by adjusting the melt rate of the feed stock. The metal flows over a weir at the end of the hearth and falls into a water-cooled chill ring, where it solidifies into a billet as it is withdrawn downward from the chamber. Vaporized impurities condense on the cold inner walls of the vacuum chamber or on special collector plates that are easily removed for cleaning. Because of the intense heat needed for the melting and refining process, the vacuum chamber is usually of double-wall construction so that large quantities of cooling water can circulate through the passages of the chamber.

Figure A-1-1.2(e) Example of electron-beam (EB) melter.

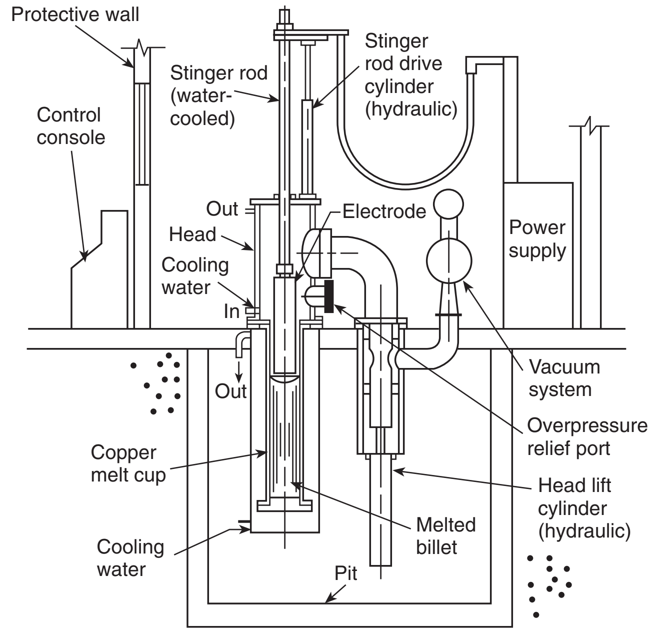


The following are some safety considerations applicable to this type of equipment.

(1) Water-cooling circuits should be constructed to be reliable to prevent steam pockets from forming in confined areas, which could result in an explosion.
(2) Beam gun controls should be designed so they do not allow the beam to become fixed on one spot, which could cause a burn-through into a water circuit.
(3) All sight ports should be covered with dark glass for eye protection while viewing the melt process.
(4) Overpressure-relief systems should be incorporated where there is potential for adverse conditions.
(5) Installations should consider emergency alternative sources of cooling water for added protection of equipment and personnel.
(6) Since accelerating voltages might run as high as 100 kV, special protection should be provided to protect personnel against x-ray exposure in addition to the high voltage hazards.

Vacuum Arc Melting and Vacuum Arc Skull Casting. Vacuum arc melting is a high-volume production method for alloying and refining metals. Alloys can be produced by sandwiching and welding strips of different metals together to produce an electrode that, after melting, results in the desired alloy. Second and third melts are sometimes necessary to refine the alloy. Most arc melters are of the consumable electrode type; however, nonconsumable electrode melters are commercially available. Figure A-1-1.2(f) illustrates the principal components of one type of consumable electrode arc melter.

Figure A-1-1.2(f) Example of vacuum arc melter.



In operation, dc voltage potential is established between the stinger rod, which has the electrode attached to it, and the water-cooled copper melt cup. The stinger rod is driven down until an arc is established between the electrode and a metal disk placed in the bottom of the melt cup. Once the arc has stabilized and melting begins, the voltage might be reduced, thus shortening the arc length and lessening the possibility of arcing to the water-cooled sidewall of the cup.

Automatic control systems are available for controlling the arc length and melt rates. A mechanical booster pumping system provides vacuum operating levels of approximately 10^{-2} torr (1.3×10^{-4} Pa). Water-cooling circuits are provided for the stinger rod, head, melt cup, solid-state power supply, cables and connections, and vacuum pumping system.

The vacuum arc skull caster is a variation of the vacuum arc melter with the essential difference that, instead of melting the electrode into a copper cup and allowing the molten metal to solidify, the electrode is melted into a cold-wall copper crucible. The crucible then is tilted, allowing the molten metal to pour into a casting mold, leaving a solidified metal lining or "skull" in the crucible.

Burn-throughs into water jackets, which allow water to come in contact with hot metal, are not uncommon in arc melting. Equipment damage can be minimized by providing overpressure-relief ports, reliable cooling water sources, well-designed and monitored cooling circuits, and well-trained operators. Blast protection walls are frequently installed for personnel protection.

A-1-3.2 Because this standard is based on the present state of the art, application to existing installations is not mandatory. Nevertheless, users are encouraged to adopt those features of this standard that are considered applicable and reasonable for existing installations.

A-1-4 Section 1-4 includes requirements for complete plans, sequence of operations, and specifications to be submitted to the authority having jurisdiction for approval. Application forms such as those in Figures A-1-4(a) and (b) can be used or might be requested to help the authority having jurisdiction in this approval process. (Variations of the forms can depend on the type of furnace or oven being furnished, its application, and the authority having jurisdiction.) Figures A-1-4(a) and (b) are two historical examples of application forms that are based on older editions of the standard. Forms consistent with current requirements should be used.

Figure A-1-4(a) Sample 1: furnace or oven manufacturer's application for acceptance.

SHEET 1 OF 2

MFR'S. JOB OR CONTRACT NO.	DATE

PART A — PLANS

NAME OF CUSTOMER (name of owner)		
ADDRESS (St. & No.)	CITY	STATE
NAME OF MANUFACTURER		
ADDRESS (St. & No.)	CITY	STATE
DRAWINGS SUBMITTED, NOS.		NO. OF SETS

INSTALLA-TION	TYPE	BATCH ☐	CONTINUOUS ☐	
	CONSISTS OF			
RATED HEAT INPUT	BTU/HR	☐ GAS BTU/FT³	☐ FUEL OIL NO. GAL/HR	☐ ELECTRIC KW
SIZE (EXTERNAL IN FT)	LENGTH	WIDTH	HEIGHT	OPERATING TEMP. °F
LOCATION OF EQUIPMENT	BLDG. NO. OR NAME		NO. OF FLOOR OR STORY	
FUEL SHUTOFF	ACCESSIBLE IN EVENT OF FIRE YES ☐ NO ☐	SEPARATE EXCESS TEMPERATURE LIMIT SWITCH SHUTS OFF HEAT YES ☐ NO ☐	SET FOR °F	
FIRE PROTECTION OF OIL QUENCH TANK	☐ NONE ☐ AUTOMATIC SPRINKLERS	☐ OPEN SPRINKLERS	☐ AUTOMATIC WATER SPRAY	☐ AUTOMATIC FIXED FOAM
	☐ IF OTHER, DESCRIBE			
TYPE OF WORK	HEAT TREATING METALS ☐ WITH SPECIAL FLAMMABLE ATMOSPHERE		☐ WITH SPECIAL INERT ATMOSPHERE	
	IF OTHER, DESCRIBE			
HEATING ARRANGE-MENT	☐ INTERNAL DIRECT-FIRED NONRECIRCULATING	☐ INTERNAL DIRECT-FIRED RECIRCULATING	☐ EXTERNAL DIRECT-FIRED RECIRCULATING	☐ EXTERNAL INDIRECT-FIRED
	☐ IF OTHER, DESCRIBE	MUFFLE YES ☐ NO ☐	RADIANT TUBES YES ☐ NO ☐	
	TYPE OF ELECTRIC HEATING ELEMENTS AND LOCATION			
	NO. OF MAIN BURNERS	NO. OF PILOT BURNERS		
METHOD OF LIGHTING–OFF	☐ PORTABLE TORCH ☐ FIXED	☐ PILOT	☐ OIL ☐ GAS	☐ SPARK IGNITOR
METHOD OF FIRING	☐ HI–LOW	☐ MODULATING	☐ ON–OFF	☐ CONTINUOUS

MIXER TYPE	☐ GAS	NO. OF MAIN BURNER INSPIRATORS	☐ ZERO-GOVERNOR TYPE	☐ ATMOSPHERIC INSPIRATOR	☐ HIGH PRESSURE 1.0 PSIG OR OVER	☐ LOW PRESSURE	☐ OTHER
		NO. OF PILOT INSPIRATORS	☐ ZERO-GOVERNOR TYPE	☐ ATMOSPHERIC INSPIRATOR	☐ HIGH PRESSURE 1.0 PSIG OR OVER	☐ LOW PRESSURE	☐ OTHER
	☐ OIL	☐ AIR (16–32 OZ) ATOMIZING		☐ ROSS OR DRY SYSTEM AIR ATOMIZING			☐ OTHER
	IF OTHER, DESCRIBE (MFR. & TYPE)						

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Figure A-1-4(a) ***(Continued)***

SHEET 2 OF 2

PROTECTION AGAINST FUEL EXPLOSION	LIGHTING-OFF	OPENINGS INTO ROOM ☐ TOP ☐ BOTTOM			
		NO FUEL & IGNITION UNTIL: ☐ TIMED PREVENTILATION BY EXH. & RECIRCULATING FANS	TIMER SETTING MIN.	☐ DOORS WIDE OPEN	☐ BURNER (F.M.) COCKS CLOSED / ☐ MEANS PROVIDED FOR CHECK OF MAIN SAFETY SHUTOFF VALVE TIGHTNESS
		PILOT-FLAME ESTABLISHING PERIOD AUTOMATICALLY LIMITED ☐ YES ☐ NO SEC.	TRIAL-FOR-IGNITION PERIOD AUTOMATICALLY LIMITED ☐ YES ☐ NO SEC.	OIL TEMP. INTERLOCK ☐ YES ☐ NO SET FOR °F	PROVED LOW-FIRE INTERLOCK ☐ YES ☐ NO
		MFR. & TYPE NO. OF F.M. COCKS AND TIMER	COMB. AIR BLOWER CANNOT BE ☐ STARTED UNTIL END OF PREVENT. (IF TIMER USED)	COMB. SAFEGUARD PROVES PILOT ☐ BEFORE MAIN SAFETY SHUTOFF VALVE OPENS	
	FIRING	HEAT CUTOFF AUTOMATICALLY, REQUIRING MANUAL OPERATION TO RESTORE, ON FAILURE OF ☐ COMBUSTION AIR ☐ RECIRCULATING FAN ☐ EXHAUST FAN ☐ FUEL PRESSURE ☐ FLAME (combustion safeguard)			
		☐ ROD OR SCANNER LOCATION ENSURES PILOT IGNITES MAIN FLAME	MANDATORY PURGE AFTER FLAME FAILURE ☐ YES ☐ NO		
	MFR. & TYPE NO.	MAIN SAFETY SHUTOFF VALVE IPS. IN.	PILOT SAFETY SHUTOFF VALVE IPS. IN.		
		COMBUSTION SAFEGUARD	PRESSURE SWITCHES	AUTOMATIC FIRE CHECKS	

PROTECTION AGAINST SPECIAL ATMOSPHERE EXPLOSION	ATMOSPHERE FIRST TURNED ON INTO: ☐ HEATED WORK SECTION ☐ COOLING SECTION				
	IF COOLING SECTION, EXPLAIN HOW HAZARD AVOIDED				
	TEMPERATURE OF THIS SECTION WHEN ATMOSPHERE TURNED ON °F	SHUTOFF °F	☐ ATMOSPHERE INTERLOCKED WITH FURNACE TEMPERATURE CONTROLLER		
	PRECAUTIONS WHEN TURNING ON AND SHUTTING OFF ATMOSPHERE	☐ INERT GAS PURGE	☐ BURN-OUT	☐ NO IGNITION SOURCE WHILE FURNACE ATMOSPHERE EXPLOSIVE	
	IF LATTER CASE, CHECK FOR NONEXPLOSIVE ATMOSPHERE IS BY	☐ GAS ANALYZER	☐ BURNING TEST SAMPLE	☐ TIME–VOLUME MEASURE	☐ NONE
	SPECIAL ATMOSPHERE GENERATOR	MANUFACTURER AND TYPE	☐ ATMOSPHERE GENERATOR OUTPUT VENTED TO OUTDOORS UNTIL GENERATOR BURNER STABLE		
		ALARM AND AUTOMATIC LOCKOUT OF FUEL & COMBUSTION AIR IF FAILURE OF: ☐ FUEL ☐ COMBUSTION AIR ☐ POWER ☐ FLAME ☐ ATMOSPHERE TEMPERATURE AT GENERATOR			
	MFR. & TYPE NO.	SAFETY SHUTOFF VALVES	PRESSURE SWITCHES		
		TEMPERATURE SWITCHES	COMBUSTION SAFEGUARDS		
PART A ACCEPTED BY	☐ AS SUBMITTED	☐ SUBJECT TO ANY CHANGES INDICATED	DATE		

PART B — MANUFACTURER'S INSPECTION & TEST (completed installation)

BURNERS	☐ LIGHTED	☐ MIXERS ADJUSTED	☐ TEMP. CONTROL SET	☐ ADJ. FOR STABLE LOW FLAME
SAFETY CONTROLS	☐ ADJUSTED	☐ TESTED FOR PROPER RESPONSE		
INSTRUCTIONS	☐ CUSTOMER'S OPERATOR INSTRUCTED	☐ PRINTED OPERATING INSTRUCTIONS LEFT	☐ APPLICATION FOR ACCEPTANCE POSTED ON CONTROL PANEL	
SIGNATURES	MFRS. FIELD REP.	TEST WITNESSED BY FOR CUSTOMER	DATE	
PART B ACCEPTED BY	☐ AS SUBMITTED	☐ SUBJECT TO ANY CHANGES INDICATED	DATE	

PART C — FIELD EXAMINATION OF COMPLETED INSTALLATION

☐ PART A CHECKED	☐ PART B CHECKED	☐ SAFETY CONTROLS TESTED	☐ ROD OR SCANNER LOCATION ASSURES PILOT IGNITES MAIN FLAME
INSTALLATION ACCEPTABLE BY			DATE

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Figure A-1-4(b) Sample 2: furnace or oven manufacturer's application for acceptance.

SHEET 1 of 2

MFR'S. JOB OR CONTRACT NO.	DATE

PART A — PLANS

NAME & ADDRESS OF CUSTOMER (OWNER)	NAME & ADDRESS OF MANUFACTURER				
DRAWINGS SUBMITTED, NOS.	NO. OF SETS				
INSTALLATION	ERECTION & ADJUSTMENTS (SEE PART B) BY: ☐ MANUFACTURER ☐ CUSTOMER	IF OTHER, DESCRIBE			
	SAFETY VENTILATION AIR FLOW TESTS (SEE PART B) TO BE MADE AFTER ERECTION BY: ☐ MANUFACTURER ☐ CUSTOMER	IF OTHER, DESCRIBE			
	TYPE ☐ BATCH ☐ CONTINUOUS	TYPE NO. OR OTHER INFORMATION			
CON-STRUCTION	☐ SHEET STEEL ON STEEL FRAME NONCOMBUSTIBLE INSULATION	IF OTHER, DESCRIBE			
RATED HEAT INPUT	☐ GAS BTU/HR	☐ FUEL OIL NO. GAL/HR	☐ ELECTRIC KW	☐ STEAM PRESS, psig	
SIZE	LENGTH (External) FT	WIDTH (External) FT	HEIGHT (External) FT	VOLUME (Internal) FT^3	OPERATING TEMP. °F
LOCATION OF EQUIPMENT	BLDG. NO. OR NAME	BUILDING FLOOR CONSTRUCTION AND NO. OF FLOOR OR STORY			
	AIR SPACE BETWEEN OVEN & WOOD FLOOR IN.	IF OTHER, DESCRIBE			
	AIR SPACE BETWEEN STACKS, DUCTS, & WOOD BLDG. CONST. IN.	IF OTHER, DESCRIBE			
	EXHAUST STACKS	DIAM. OR SIZE IN.	METAL GAUGE (USS)	☐ INSULATED	NO. OF CLEANOUT (ACCESS) DOORS
EXPLOSION VENTING AREA	OPEN ENDS FT^2	LOOSE ROOF PANELS FT^2	ACCESS DOORS WITH EXPLOSION LATCHES FT^2		
	MANUFACTURER AND TYPE LATCH	TOTAL AREA FT^2	VENT RATIO $\frac{\text{VENT AREA}}{\text{INTERNAL VOLUME}} =$		
FUEL SHUTOFF	ACCESSIBLE IN EVENT OF FIRE ☐ YES ☐ NO				
FIRE PROTECTION IN OVEN	☐ NONE ☐ AUTOMATIC SPRINKLERS ☐ OPEN SPRINKLERS ☐ CO_2 ☐ STEAM	DRAWINGS SUBMITTED ☐ YES ☐ NO			
	☐ OTHER (DESCRIBE)	☐ SEPARATE EXCESS TEMPERATURE LIMIT SWITCH WITH MANUAL RESET	SET FOR °F		
FIRE PROTECTION FOR DIP TANK & DRAINBOARD	DRAWINGS SUBMITTED ☐ YES ☐ NO	FIXED AUTO. CO_2 ☐ YES ☐ NO	☐ OTHER (DESCRIBE)		
	OVERFLOW VALVES ☐ YES ☐ NO	DUMP VALVES ☐ YES ☐ NO	SALVAGE TANK ☐ YES ☐ NO	IS HEAT SHUTOFF AUTOMATICALLY ON FAILURE OF CONVEYOR ☐ YES ☐ NO	
TYPE OF WORK	IMPREGNATED-COATED ABSORBENT MATERIAL ☐ PAPER ☐ CLOTH	☐ LITHOGRAPH COATING ☐ VARNISH ELECT. COILS ☐ GRAVURE PRESS ☐ FOOD BAKING ☐ CORES OR MOLDS			
	METAL ☐ DIPPED ☐ FLOW-COATED ☐ SPRAYED	☐ OTHER (DESCRIBE)			
SOLVENTS ENTERING OVEN	NAME OF SOLVENT USED	LENGTH OF BAKE MIN.	MAX. SOLVENT FOR WHICH OVEN DESIGNED CONTINUOUS GAL/HR BATCH GAL/BATCH		
DESIGNED SAFETY VENTILATION	ARRANGEMENT ☐ SEPARATE CENTRIFUGAL EXHAUSTER ☐ RECIRCULATING FAN WITH SPILL ☐ NATURAL DRAFT STACK ☐ OPENINGS INTO ROOM	FILTERS ON FRESH AIR INTAKE ☐ YES ☐ NO			
	FRESH AIR ADMITTED INTO OVEN CFM REFERRED TO 70° F	OPENING WITH DAMPER CLOSED FRESH AIR INLET % EXHAUST OUTLET %	DOES CONVEYOR STOP AUTOMATICALLY ON FAILURE OF SAFETY EXHAUST FANS ☐ YES ☐ NO		
	FAN MFR. SIZE, TYPE	WHEEL DESIGN (BLADE TIP) ☐ RADIAL TIP ☐ BACKWARD INCLINED ☐ FORWARD CURVED	DIAM. IN.	TIP SPEED FT/MIN	

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Figure A-1-4(b) *(Continued)*

SHEET 2 OF 2

HEATING ARRANGE-MENT	☐ INTERNAL DIRECT-FIRED NONRECIRCULATING ☐ INTERNAL DIRECT-FIRED RECIRCULATING ☐ EXTERNAL DIRECT-FIRED RECIRCULATING ☐ EXTERNAL INDIRECT-FIRED
	☐ OTHER (DESCRIBE)
	TYPE OF ELECTRIC HEATING ELEMENTS AND LOCATION
	NO. OF MAIN BURNERS / NO. OF PILOT BURNERS / CAN DRIPPINGS OFF WORK FALL ON HEATING ELEMENTS ☐ YES ☐ NO
METHOD OF LIGHTING–OFF	☐ PORTABLE TORCH ☐ FIXED ☐ PILOT ☐ OIL ☐ GAS ☐ SPARK IGNITOR
METHOD OF FIRING	☐ HI–LOW ON–OFF ☐ ☐ MODULATING CONTINUOUS ☐ ☐ AUTOMATIC-LIGHTED MANUAL-LIGHTED ☐ ☐ SEMI-AUTOMATIC-LIGHTED
	TYPE OF PILOT ☐ CONTINUOUS ☐ INTERRUPTED ☐ INTERMITTENT ☐ OTHER (DESCRIBE)
MIXER TYPE	☐ GAS — NO. MAIN BURNER INSPIRATORS ☐ ZERO-GOVERNOR TYPE ☐ ATMOSPHERIC INSPIRATOR ☐ HIGH PRESSURE ☐ LOW PRESSURE
	NO. PILOT INSPIRATORS ☐ ZERO-GOVERNOR TYPE ☐ ATMOSPHERIC INSPIRATOR ☐ HIGH PRESSURE ☐ LOW PRESSURE
	☐ OIL ☐ AIR (16–32 OZ) ATOMIZING
	☐ OTHER — OTHER TYPE MIXERS OR OIL BURNERS INCLUDING PILOTS (MFR. & TYPE)
PROTECTION AGAINST FUEL EXPLOSION — LIGHTING-OFF	NO FUEL AND IGNITION UNTIL: ☐ TIMED PREVENTILATION BY EXHAUST AND RECIRC. FANS / TIMER SETTING MIN. / ☐ DOORS WIDE OPEN / ☐ BURNER (F.M.) COCKS CLOSED / ☐ MEANS PROVIDED FOR CHECK OF MAIN SAFETY SHUTOFF VALVE TIGHTNESS
	PILOT-FLAME-ESTABLISHING PERIOD AUTOMATICALLY LIMITED ☐ YES ☐ NO SEC. / TRIAL-FOR-IGNITION PERIOD AUTOMATICALLY LIMITED ☐ YES ☐ NO SEC. / OIL TEMP. INTERLOCK ☐ YES ☐ NO SET FOR °F / PROVED LOW-FIRE INTERLOCK ☐ YES ☐ NO
	MFR. AND TYPE NO. OF F.M. COCKS & TIMER / ☐ COMBUSTION AIR BLOWER CANNOT BE STARTED UNTIL END OF PREVENT. (IF TIMER USED) / ☐ COMBUSTION SAFEGUARD PROVES PILOT BEFORE MAIN SAFETY SHUTOFF VALVE OPENS
FIRING	HEAT CUTOFF AUTOMATICALLY, REQUIRING MANUAL OPERATION TO RESTORE, ON FAILURE OF ☐ COMBUSTION AIR ☐ RECIRCULATING FAN ☐ SAFETY EXHAUST FAN ☐ HIGH AND LOW GAS PRESSURE ☐ LOW OIL PRESSURE ☐ FLAME (Combustion Safeguard)
	☐ ROD OR SCANNER LOCATION ENSURES PILOT IGNITES MAIN FLAME / MANDATORY PURGE AFTER FLAME FAILURE ☐ YES ☐ NO
MANU-FACTURER & TYPE NO.	MAIN SAFETY SHUTOFF VALVE IPS. IN. / PILOT SAFETY SHUTOFF VALVE IPS. IN.
	COMBUSTION SAFEGUARD / PRESSURE SWITCHES / AIRFLOW SWITCHES
PART A ACCEPTED	☐ AS SUBMITTED ☐ SUBJECT TO ANY CHANGES INDICATED / DATE / BY

PART B — MANUFACTURER'S INSPECTION & TEST

SAFETY VENTILATION	CFM REF. TO 70° F / MEASURED BY (SPECIFY) ☐ PITOT ☐ OTHER / MEASURED WITH FRESH AIR INLET & EXHAUST OUTLET DAMPERS IN MAXIMUM CLOSED POSITION ☐ YES ☐ NO
BURNERS	☐ LIGHTED ☐ MIXERS ADJUSTED ☐ TEMP. CONTROL SET ☐ ADJ. FOR STABLE LOW FLAME
SAFETY CONTROLS	☐ ADJUSTED ☐ TESTED FOR PROPER RESPONSE
INSTRUCTIONS	☐ CUSTOMER'S OPERATOR INSTRUCTED ☐ PRINTED OPERATING INSTRUCTIONS LEFT ☐ APPLICATION FOR ACCEPTANCE POSTED ON CONTROL PANEL
SIGNATURES	MFR'S. FIELD REP. / TEST WITNESSED BY FOR CUSTOMER / DATE
PART B ACCEPTED	☐ AS SUBMITTED ☐ SUBJECT TO ANY CHANGES INDICATED / DATE / BY

PART C — FIELD EXAMINATION OF COMPLETED INSTALLATION

☐ PART A CHECKED	☐ PART B CHECKED	☐ SAFETY CONTROLS TESTED	☐ ROD OR SCANNER LOCATION ASSURES PILOT IGNITES MAIN FLAME
ENGINEER'S SIGNATURE			DATE

A-1-4.3.1 The proximity of electrical equipment and flammable gas or liquid in an electrical enclosure or panel is a known risk and would be considered a classified area. Article 500 of NFPA 70, *National Electrical Code*®, should be consulted.

Conduit connecting devices handling flammable material might carry this material to an electrical enclosure if the device fails, creating a classified area in that enclosure. Sealing of such conduits should be considered.

A-1-4.3.3 Unless otherwise required by the local environment, ovens and furnaces and the surrounding area are not classified as a hazardous (classified) location. The primary source of ignition associated with an oven installation is the oven heating system or equipment or materials heated. The presence of these ignition sources precludes the need for imposing requirements for wiring methods appropriate for a hazardous (classified) location. Refer to Section 3-3 of NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, and Section 3-3 of NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, regarding equipment with open flames or other ignition sources. In addition, ovens or furnaces are considered unclassified internally because safety depends upon ventilation.

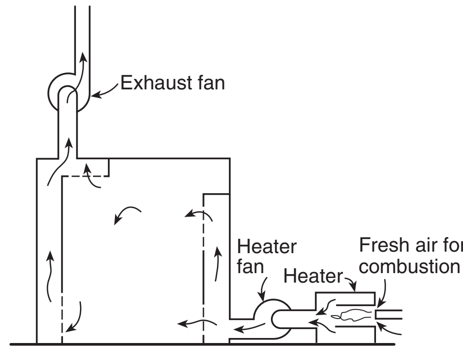
A-2-1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A-2-1 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-2-1 Heating System, Direct-Fired. The following are different types of direct-fired heating systems.

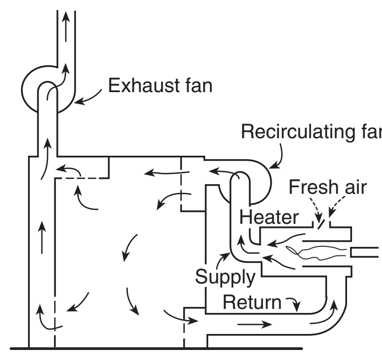
Heater: Direct-Fired, External, Nonrecirculating. A direct-fired, external heater arranged so that products of combustion are discharged into the oven chamber without any return or recirculation from the oven chamber. *[See Figure A-2-1(a).]*

Figure A-2-1(a) Example of a direct-fired, external, nonrecirculating heater.



Heater: Direct-Fired, External, Recirculating-Through. A direct-fired, external heater arranged so that oven atmosphere is recirculated to the oven heater and is in contact with the burner flame. *[See Figure A-2-1(b).]*

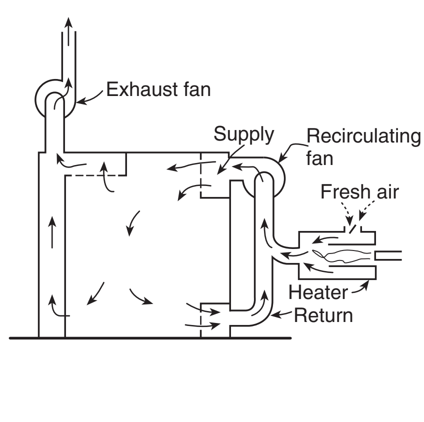
Figure A-2-1(b) Example of a direct-fired, external, recirculating-through heater.



Heater: Direct-Fired, Internal, Nonrecirculating. A combustion chamber of a recirculating oven heater that may be permitted to be built within an oven chamber not substantially separated from the oven atmosphere by gastight construction.

Heater: Direct-Fired, External, Recirculating-Not-Through. A heating system constructed so that the oven atmosphere circulates through a blower with products of combustion admitted to the recirculating ductwork, but without the oven atmosphere actually passing through the combustion chamber. *[See Figure A-2-1(c).]*

Figure A-2-1(c) Example of a direct-fired, external, recirculating-not-through heater.



A-2-1 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-2-1 Pump, Roughing. The roughing pump also can be used as the backing (fore) pump for the diffusion pump, or the roughing pump can be shut off and a smaller pump can be used as the backing (fore) pump where the gas load is relatively small.

A-2-1 Range, Explosive. See NFPA 325, *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids.*

A-3-1.1.4 For additional information, refer to NFPA 31, *Standard for the Installation of Oil-Burning Equipment;* NFPA 54, *National Fuel Gas Code;* and NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.*

A-3-1.3.3 The hazard is particularly severe where vapors from dipping operations could flow by means of gravity to ignition sources at or near floor level. See NFPA 30, *Flammable and Combustible Liquids Code;* NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials;* and NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids.*

A-3-1.4.2 The following procedure should be followed if the furnace is located in contact with a wood floor or other combustible floor and the operating temperature is above 160°F (71°C).

Combustible floor members should be removed and replaced with a monolithic concrete slab that extends a minimum of 3 ft (1 m) beyond the outer extremities of the furnace.

Air channels, either naturally or mechanically ventilated, should be provided between the floor and the equipment (perpendicular to the axis of the equipment or noncombustible insulation, or both). This should be adequate to prevent surface temperatures of floor members from exceeding 160°F (71°C).

A-3-2.12 Fuel-fired or electric heaters should not be located directly under the product being heated where combustible materials might drop and accumulate. Neither should they be located directly over readily ignitible materials such as cotton unless for a controlled exposure period, as in continuous processes where additional automatic provisions or arrangements of guard baffles, or both, preclude the possibility of ignition.

A-3-2.15 See ASME *Boiler and Pressure Vessel Code*, Section VIII. Also see API 510, *Pressure Vessel Inspection Code,* and API 570, *Piping Inspection Code.*

Where subject to corrosion, metal parts should be adequately protected.

A-3-3.1 For additional information regarding relief of equipment and buildings housing the equipment, see NFPA 68, *Guide for Venting of Deflagrations.*

A-3-3.4 The location for explosion relief is a critical concern and needs to be close to the ignition source.

The heater box is part of the oven system and needs to have explosion relief provided. Personnel considerations and proximity to other obstructions can impact the location selected for these vents.

A-3-3.6 Industry experience indicates that a typical oven enclosure built to withstand a minimum of 0.5 psig (3.45 kPa) surge overpressure with explosion-relief vents having a maximum weight per area of 5 lb/ft^2 (24.4 kg/m^2) meets the requirements of 3-3.6.

A-3-3.7 The intent of providing explosion relief in furnaces is to limit damage to the furnace and to reduce the risk of personnel injury due to explosions. To achieve this, relief vents and doors should be sized so that their inertia does not preclude their ability to relieve internal explosion pressures.

A-3-4 For additional information, refer to NFPA 31, *Standard for the Installation of Oil-Burning Equipment;* NFPA 54, *National Fuel Gas Code;* and NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.*

A-3-4.3.4 Ducts that pass through fire walls should be avoided.

A-3-4.3.8 All interior laps in the duct joints should be made in the direction of the flow.

A-3-6.1 Vacuum pumps might be the ejector, liquid ring, mechanical, cryopump, or diffusion type.

A-3-6.3 It is recommended that diffusion pumps be charged with a vacuum grade of silicon-based fluid to reduce the risk of explosion on inadvertent exposure to air when heated. Diffusion pump fluids with equivalent or superior fire resistance should be considered.

A-3-7.1 Vacuum gauges might contain controlling devices to operate equipment sequentially.

A-3-9.2 The furnace cooling system can include a vessel cooling system and one or more methods for cooling material in process. The systems might include gas quenching, oil quenching, or water quenching. Internal or external heat exchangers may be permitted to be used and generally require supplementary cooling. Special atmospheres might be used for cooling.

A-3-9.3 Consideration should be given to the provision of flow indicators or temperature gauges on exit cooling lines.

A-3-10 After the thermal cycle has been completed, the work load either is transferred to a gas quenching vestibule or is gas-quenched in the heating zone. Gas quenching is performed by introducing a cooling gas (usually nitrogen, hydrogen, argon, or helium) until the pressure reaches a predetermined level [usually from 2 psig to 12 psig (13.8 kPa to 82.7 kPa) above atmospheric] and recirculating the cooling gas through a heat exchanger and over the work by means of a fan or blower. The heat exchanger and fans or blower are either internal (within the furnace vacuum chamber) or external (outside the furnace vacuum chamber).

A-4-2.1.1 The term *ignition temperature* means the lowest temperature at which a gas–air mixture can ignite and continue to burn. This is also referred to as the *autoignition temperature.* Where burners supplied with a gas–air mixture in the flammable range are heated above the autoignition temperature, flashbacks can occur. In general, such temperatures range from 870°F to 1300°F (465°C to 704°C). A much higher temperature is needed to ignite gas dependably. The temperature necessary is slightly higher for natural gas than for manufactured gases, but for safety with manufactured gases, a temperature of about 1200°F (649°C) is needed, and for natural gas, a temperature of about 1400°F (760°C) is needed. Additional safety considerations should be given to dirt-laden gases, sulfur-laden gases, high-hydrogen gases, and low-Btu waste gases.

Flame Propagation and Explosive Range. The term *rate of flame propagation* means the speed at which a flame progresses through a combustible gas–air mixture under the pressure, temperature, and mixture conditions existing in the combustion space, burner, or piping under consideration. *(See Figure A-4-2.1.1 and Table A-4-2.1.1.)*

Figure A-4-2.1.1 Ignition velocity curves for typical flammable gases.

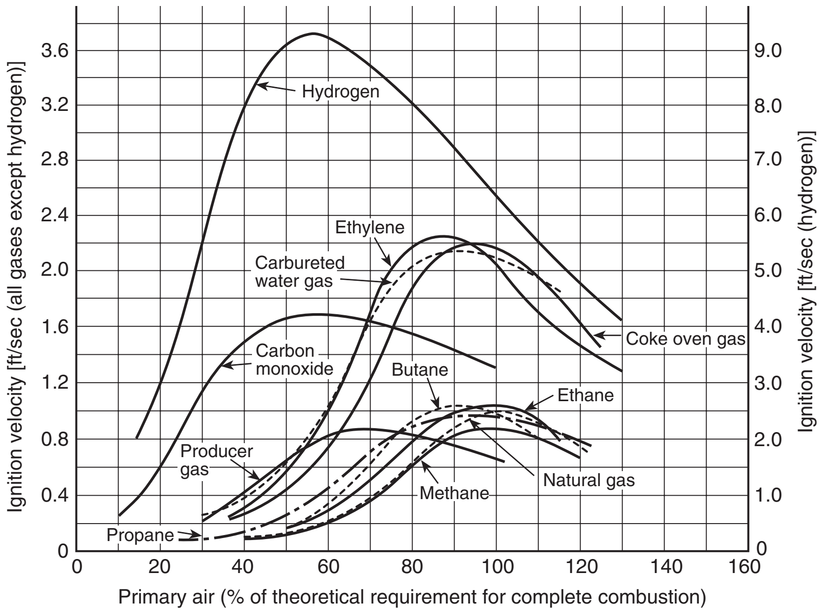


Table A-4-2.1.1 Properties of Typical Flammable Gases

Flammable Gas	Molecular Weight	Btu/cf	Autoignition (°F)	LEL % by Volume	UEL % by Volume	Vapor Density (Air=1)	cf Air Req'd to Burn 1 cf of Gas
Butane	58	3200	550	1.9	8.5	2	31
CO	28	310	1128	12.5	74	0.97	2.5
Hydrogen	2	311	932	4	74.2	0.07	2.5
Natural gas (high Btu type)	18.6	1115	—	4.6	14.5	0.64	10.6
Natural gas (high methane type)	16.2	960	—	4	15	0.56	9
Natural gas (high inert type)	20.3	1000	—	3.9	14	0.70	9.4
Propane	44	2500	842	2.1	9.5	1.57	24

A-4-2.2 For additional information, refer to NFPA 54, *National Fuel Gas Code.*

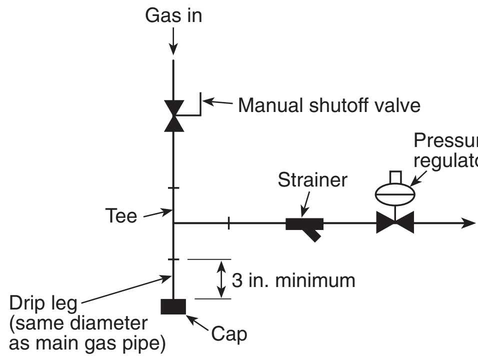
A-4-2.4.3 Whenever the fuel train is opened for service, the risk of dirt entry exists. It is not required that existing piping be opened for the sole purpose of the addition of a filter or strainer.

A-4-2.4.4 A typical piping arrangement for a drip leg or sediment trap and gas filter or strainer is shown in Figure A-4-2.4.4.

A-4-2.6.1 In the design, fabrication, and utilization of mixture piping, it should be recognized that the air–fuel gas mixture might be in the flammable range.

A-4-2.6.3.1 Two basic methods generally are used. One method uses a separate fire check at each burner, the other a fire check at each group of burners. The second method generally is more practical if a system consists of many closely spaced burners.

Figure A-4-2.4.4 Typical piping arrangement for a drip leg and strainer.



A-4-2.6.3.3 Acceptable safety blowouts are available from some manufacturers of air–fuel mixing machines. They incorporate all the following components and design features:

(1) Flame arrester
(2) Blowout disk
(3) Provision for automatically shutting off the supply of air–gas mixture to the burners in the event of a flashback passing through an automatic fire check

A-4-2.7.4 Testing of radiant tubes should include subjecting them to thermal cycling typical for the furnace application and then verifying their ability to withstand overpressure developed by a fuel–air explosion. Overpressure testing can be done in one of the following two ways:

(a) Statically pressurize the tube until it fails. Compare this pressure to the maximum pressure (from literature) that can be developed in a contained deflagration of an optimum fuel–air mixture.

(b) After partially blocking the open end of the tube to simulate a heat exchanger, fill the tube with a well-mixed stoichiometric fuel–air mixture (10 volumes of air to one volume of fuel for natural gas). Ignite the mixture at the closed end of the tube. Measure the pressure developed. Compare this pressure to the maximum pressure (from literature) that can be developed in a contained deflagration of an optimum fuel–air mixture.

A-4-2.8.1 A burner is suitably ignited when combustion of the air–fuel mixture is established and stable at the discharge port(s) of the nozzle(s) or in the contiguous combustion tunnel.

A-4-3.1.1 In the design and use of oil-fired units, the following should be considered.

(a) Unlike fuel gases, data on many important physical/chemical characteristics are not available for fuel oil, which, being a complex mixture of hydrocarbons, is relatively unpredictable.

(b) Fuel oil has to be vaporized prior to combustion. Heat generated by the combustion commonly is utilized for this purpose, and oil remains in the vapor phase as long as sufficient temperature is present. Under these conditions, oil vapor can be treated as fuel gas.

(c) Unlike fuel gas, oil vapor condenses into liquid when the temperature falls too low and revaporizes whenever the temperature rises to an indeterminate point. Therefore, oil in a cold furnace can lead to a hazardous condition, because, unlike fuel gas, it cannot be purged. Oil can vaporize (to become a gas) when, or because, the furnace operating temperature is reached.

(d) Unlike water, for example, there is no known established relationship between temperature and vapor pressure for fuel oil. For purposes of comparison, a gallon of fuel oil is equivalent to 140 ft^3 (4.0 m^3) of natural gas; therefore, 1 oz (0.03 kg) equals approximately 1 ft^3 (0.03 m^3).

A-4-3.2 For additional information, refer to NFPA 31, *Standard for the Installation of Oil-Burning Equipment.*

A-4-3.3.4 A long circulating loop, consisting of a supply leg, a back-pressure regulating valve, and a return line back to the storage tank, is a means of reducing air entrainment.

Manual vent valves might be needed to bleed air from the high points of the oil supply piping.

A-4-3.3.6 The weight of fuel oil is always a consideration in vertical runs. When going up, pressure is lost. One hundred psig (689 kPa) with a 100-ft (30.5-m) lift nets only 63 psig (434 kPa). When going down, pressure increases. One hundred psig (689 kPa) with a 100-ft (30.5-m) drop nets 137 psig (945 kPa). This also occurs with fuel gas, but it usually is of no importance. However, it should never be overlooked where handling oils.

A-4-3.4.3.2 Customarily, a filter or strainer is installed in the supply piping to protect the pump. However, this filter or strainer mesh usually is not sufficiently fine for burner and valve protection.

A-4-3.4.5 Under some conditions, pressure-sensing on fuel oil lines downstream from feed pumps can lead to gauge failure when rapid pulsation exists. A failure of the gauge can result in fuel oil leakage. The gauge should be removed from service after initial burner start-up or after periodic burner checks. An alternative approach would be to protect the gauge during service with a pressure snubber.

A-4-3.6.1 The atomizing medium might be steam, compressed air, low pressure air, air–gas mixture, fuel gas, or other gases. Atomization also might be mechanical (mechanical-atomizing tip or rotary cup).

A-4-3.8.1 A burner is suitably ignited when combustion of the air–fuel mixture is established and stable at the discharge port(s) of the nozzle(s) or in the contiguous combustion tunnel.

A-4-4.1 Oxy-fuel burners often are utilized in conjunction with arc melting furnaces to augment electric heating. Some of these burners utilize air as well. Stationary burners are attached to the furnace shell or cover, or both. Movable burners that normally are not attached to the furnace are suspended from structural members outside a furnace door. They are manipulated from the operating floor, and the oxygen and fuel are introduced into the furnace through long, concentric pipes.

Conventional flame safeguards are impractical in conjunction with oxy-fuel burners in arc furnaces because of the radio frequency noise associated with the arcs. The electric arc is a reliable means of ignition for the burners, once it has been established. After the arc has been established, the high temperatures inside an arc furnace cause the ignition of significant accumulations of oxygen and fuel.

Using oxygen to augment or to substitute for combustion air in industrial furnace heating systems presents new safety hazards for users acquainted only with air–fuel burners.

One group of hazards arises from the exceptional reactivity of oxygen. It is a potent oxidizer; therefore, it accelerates burning rates. It also increases the flammability of substances that generally are considered nonflammable in air. A fire fed by oxygen is difficult to extinguish.

Special precautions are needed to prevent oxygen pipeline fires — that is, fires in which the pipe itself becomes the fuel. Designers and installers of gaseous oxygen piping should familiarize themselves with standards and guidelines referenced in this standard on pipe sizing, materials of construction, and sealing methods. Gaseous oxygen should flow at relatively low velocity in pipelines built of ferrous materials, because friction created by particles swept through steel pipe at a high speed can ignite a pipeline. For this reason, copper or copper-based alloy construction is customary where the oxygen velocity needs to be high, such as in valves, valve trim areas, and in orifices.

Oxygen pipelines should be cleaned scrupulously to rid them of oil, grease, or any hydrocarbon residues before oxygen is introduced. Valves, controls, and piping elements that come in contact with oxygen should be inspected and certified as "clean for oxygen service." Thread sealants, gaskets and seals, and valve trim should be oxygen-compatible; otherwise they could initiate or promote fires. Proven cleaning and inspection methods are described in Compressed Gas Association guidelines provided in Appendix G.

Furnace operators and others who install or service oxygen piping and controls should be trained in the precautions and safe practices for handling oxygen. For example, smoking or striking a welding arc in an oxygen-enriched atmosphere could start a fire. Gaseous oxygen has no odor and is invisible, so those locations in which there is a potential for leaks are off-limits to smokers and persons doing hot work. The location of such areas should be posted. Persons who have been in contact with oxygen should be aware that their clothing is extremely flammable until it has been aired. Equipment or devices that contain oxygen should never be lubricated or cleaned with agents that are not approved for oxygen service.

Oxygen suppliers are sources of chemical material safety data sheets (MSDS) and other precautionary information for use in employee training. Users are urged to review the safety requirements in this standard and adopt the recommendations.

Another group of hazards is created by the nature of oxy-fuel and oxygen-enriched air flames. Because they are exceptionally hot, these flames can damage the burners, ruin work in process and furnace internals, and even destroy refractory insulation that was intended for air–fuel heating. Oxygen burner systems and heating controls should have quick-acting, reliable means for controlling heat generation.

Air that has been enriched with oxygen causes fuel to ignite very easily, because added oxygen increases the flammability range of air–fuel mixtures. Therefore, preignition purging is critical where oxygen is used.

Oxygen is also a hazard for persons entering furnaces to perform inspections or repairs. Strict entry procedures for confined spaces should be implemented. They should include analyses for excess oxygen (oxygen contents in excess of 20.9 percent) in addition to the usual atmosphere tests for oxygen deficiency and flammability.

A-4-4.3.2 CGA G-4.4, *Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems*, specifies maximum gas velocity criteria, materials of construction, installation methods, joining methods, metering methods, use of filters, and specifications for oxygen-compatible sealing materials, gasket materials, and thread sealants.

A-4-4.3.3 See CGA G-4.1, *Cleaning Equipment for Oxygen Service.*

A-4-4.3.4 This requirement is intended to prevent the contamination of surfaces that must be clean for oxygen service from the oil normally present in plant compressed air.

A-4-4.3.9 See CGA G-4.4, *Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems.*

A-4-4.3.11 Commercial-grade carbon steel pipe exhibits a marked reduction in impact strength when cooled to sub-zero temperatures. Consequently, it is vulnerable to impact fracture if located downstream from a liquid oxygen vaporizer running beyond its rated vaporization capacity or at very low ambient temperatures.

A-4-4.5.2 Diffusers commonly are used to disperse oxygen into an airstream, effecting rapid and complete mixing of the oxygen into the air. High-velocity impingement of oxygen is a potential fire hazard.

A-4-6.3 Vacuum furnaces using induction, resistance, electron beam, plasma arc, or electric arc heating systems include an electric power supply with a high demand current.

High-voltage supply used for electron beam, plasma arc, or ion discharge furnace units might have unique safety considerations.

A-4-6.5.2.1 Transformers should be of the dry, high fire–point, or less flammable liquid type. Dry transformers should have a 270°F (150°C) rise insulation in compliance with Section 4.03 of NEMA TR 27, *Commercial, Institutional and Industrial Dry-Type Transformers.*

A-4-7.1 Fluid heating systems are used to heat lumber dry kilns, plywood veneer dryers, carpet ranges, textile ovens, and chemical reaction vessels. A fluid heating system typically consists of a central heat exchanger to heat the thermal fluid. Firing can be by conventional gas or oil burners. The hot gases then pass through a heat exchanger to indirectly heat the thermal fluid. The heat exchanger can be a separate, stand-alone unit or an integral part of the heater. Conventional water-tube boilers have been used as heaters, with thermal fluid replacing the water.

In addition to steam and water, special oils have been developed for this type of application, with flash points of several hundred degrees Fahrenheit. For maximum thermal efficiency, they are usually heated above their flash points, making an oil spill especially hazardous. Also, because of the high oil temperatures, it is usually necessary to keep the oil circulation through the heat exchanger at all times to prevent oil breakdown and tube fouling. Diesel-driven pumps or emergency generators are usually provided for this purpose in case of a power outage. Oil circulation can even be needed for a period of time after burner shutdown due to the residual heat in the heater.

A-4-7.2.1 Suitable relief valves should be provided where needed. Where relief valves are provided, they should be piped to a safe location. See design criteria in API RP 520 Pt I, *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries, Part I — Sizing and Selection*, and API RP 520 Pt II, *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries, Part II — Installation.*

A-4-7.2.3 If a combustible heat transfer fluid is used, consideration should be given to the use of automatic-actuating fire-safe isolation valves. The actuating mechanism should operate even if exposed to high temperatures. Fireproofing of the mechanism to maintain operational integrity could be necessary.

A *fire-safe valve* is one that provides a relatively tight valve-seat shutoff during temperatures that are high enough to destroy seals. The stem packing and gasketed body joints must also be relatively liquidtight during exposure to high temperatures.

A-4-8.1 Suitable materials generally include graphite, molybdenum, tantalum, tungsten, and others.

A-4-8.3 Where dissimilar metals are heated in contact with each other, particularly where they are oxide-free and used within a vacuum furnace, they can react and form alloys or a eutectic. The result is an alloy that melts at a considerably lower temperature than the melting points of either base metal.

Some eutectic-forming materials are listed in Table A-4-8.3 with a critical melting temperature. Operating temperatures near or above these points should be considered carefully.

Table A-4-8.3 Eutectic Melting Temperatures

Material	Temperature	
	°F	°C
Moly/nickel	2310	1266
Moly/titanium	2210	1210
Moly/carbon	2700	1482
Nickel/carbon	2310	1166
Nickel/tantalum	2450	1343
Nickel/titanium	1730	943

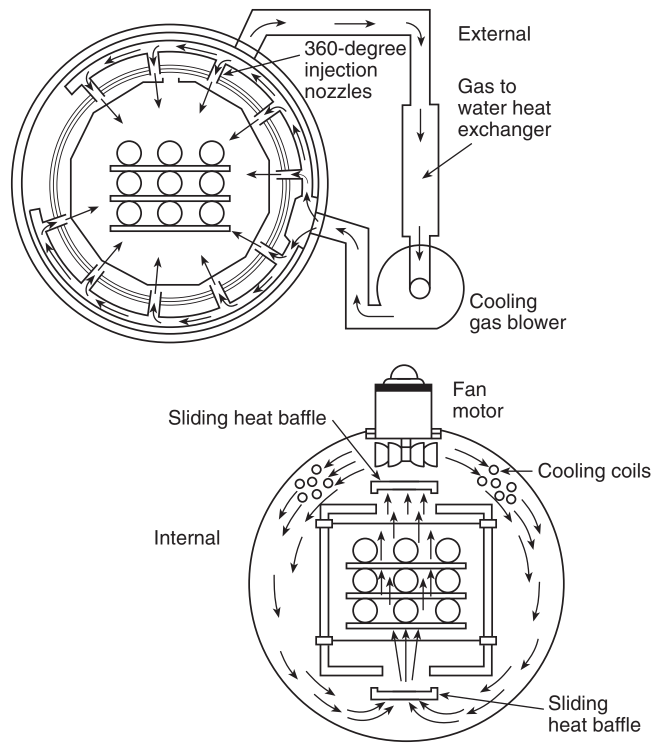
A-4-9 The heat energy produced by the heating elements transfers into the work principally by means of radiation and through the insulation or heat shields into the cooled walls of the vacuum vessel. The cooling medium is continually circulated through the walls of the vessel, maintaining a cold wall. Generally, water is used as the cooling medium.

A-4-9.1 Examples of proper insulation include graphite wool, alumina/silica fibers, and other materials.

A-4-9.2 Molybdenum, tantalum, tungsten, palladium, and 304/316 stainless steel are examples of acceptable metals to be used for heat shields.

A-4-9.3 Figure A-4-9.3 provides examples of some gas quenching methods.

Figure A-4-9.3 Examples of some gas quenching methods.



A-5-1.2 For the protection of personnel and property, careful consideration should be given to the supervision and monitoring of conditions that could cause, or could lead to, a real or potential hazard on any installation.

A-5-2.11 This control circuit and its nonfurnace-mounted or furnace-mounted control and safety components should be housed in a dusttight panel or cabinet, protected by partitions or secondary barriers, or separated by sufficient spacing from electrical controls employed in the higher voltage furnace power system. Related instruments might or might not be installed in the same control cabinet.

The door providing access to this control enclosure might include means for mechanical interlock with the main disconnect device required in the furnace power supply circuit.

Temperatures within this control enclosure should be limited to 125°F (52°C) for suitable operation of plastic components, thermal elements, fuses, and various mechanisms that are employed in the control circuit.

A-5-3.3.1 Failure modes include, but are not limited to, all of the following:

(1) Failure of CPU to execute the program
(2) Failure of the system to recognize changes in input or output status
(3) Failure of the I/O module to scan input and output signals
(4) Failure of input to respond to the action of the connected device
(5) Failure of the program to consult input or external information sources correctly
(6) Failure of output to respond to CPU instructions
(7) Failure of a memory location or register

A-5-6.4 Some systems work at very low combustion air pressures that cannot be detected reliably by conventional pressure switches. As a result, many of the combustion air pressure switches are set at a value that renders them essentially out of the circuit.

A-5-7.2.3 An example of a leak test procedure for safety shutoff valves on direct gas-fired ovens with a self-piloted burner and intermittent pilot follows.

With the oven burner(s) shut off, the main shutoff valve open, and the manual shutoff valve closed, proceed as follows.

(a) The tube should be placed in test connection 1 and immersed just below the surface of a container of water.

(b) The test connection valve should be opened. If bubbles appear, the valve is leaking and the manufacturer's instructions should be referenced for corrective action. The auxiliary power supply to safety shutoff valve No. 1 should be energized and the valve should be opened.

(c) The tube should be placed in test connection 2 and immersed just below the surface of a container of water.

(d) The test connection valve should be opened. If bubbles appear, the valve is leaking and the manufacturer's instructions should be referenced for corrective action.

This procedure is predicated on the piping diagram shown in Figure A-5-7.2.3(a) and the wiring diagram shown in Figure A-5-7.2.3(b).

Figure A-5-7.2.3(a) Example of a gas piping diagram for leak test.

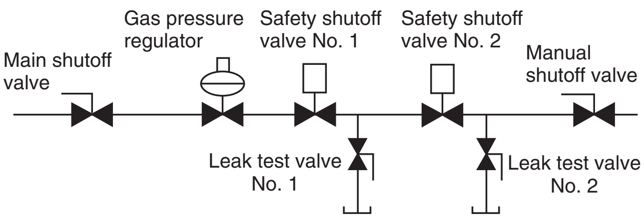
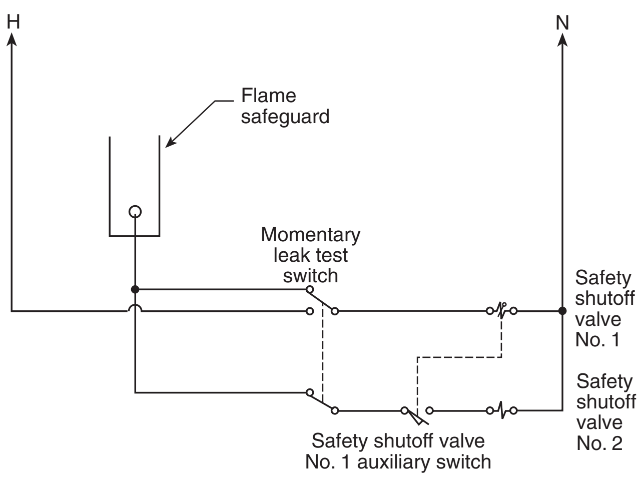


Figure A-5-7.2.3(b) Example of a wiring diagram for leak test.



A-5-9.2 Ultraviolet detectors can fail in such a manner that the loss of flame is not detected. When they are placed in continuous service, failures can be detected by using a self-checking ultraviolet detector or by periodically testing the detector for proper operation.

A-5-9.2.2 Two examples of burner arrangements considered to be a single burner with one flame safeguard installed at the end of the assembly are shown in Figures A-5-9.2.2(a) and A-5-9.2.2(b).

A-5-11 Wherever the temperature of the fuel oil can drop below a safe level, the increased viscosity prevents proper atomization. No. 2 and No. 4 fuel oils can congeal if their temperature falls below their pour point, whether or not preheaters are used.

Wherever the temperature of the fuel oil can rise above a safe level, vaporization of the oil takes place before atomization and causes a reduction in fuel volume severe enough to create substantial quenching of the flame.

A-5-16 The excess temperature set point should be set at least 100°F (56°C) below the autoignition temperature of the flammable material being processed through the oven, or 50°F (28°C) above the oven temperature control set point, whichever is applicable to the material being processed.

Should the operating temperature instrument fail and the excess temperature instrument be set between 200°F and 300°F (111°C and 167°C) above the control set point, the oven exhaust blower scfm (standard cubic feet per minute) will be reduced, lowering safety ventilation, which could cause a flammable vapor explosion.

The dwell time in high temperature, multiple-zone curing, drying, and baking ovens, designed to rapidly preheat the material, should not autoignite the material being processed, or reduce the safety ventilation, upon the failure of the temperature control instrument.

A-5-18.1.1 Abnormal conditions that could occur and require automatic or manual de-energization of affected circuits are as follows:

(1) A system fault (short circuit) not cleared by normally provided branch-circuit protection *(see NFPA 70, National Electrical Code)*
(2) The occurrence of excess temperature in a portion of the furnace that has not been abated by normal temperature-controlling devices
(3) A failure of any normal operating controls where such failure can contribute to unsafe conditions
(4) A loss of electric power that can contribute to unsafe conditions

A-5-18.1.4 The requirements of 5-18.1.4 could require derating some components as listed by manufacturers for uses such as for other types of industrial service, motor control, and as shown in Table A-5-18.1.4.

Figure A-5-9.2.2(a) An example of combustion safeguard supervising a pilot for a continuous line burner during light-off and the main flame alone during firing.

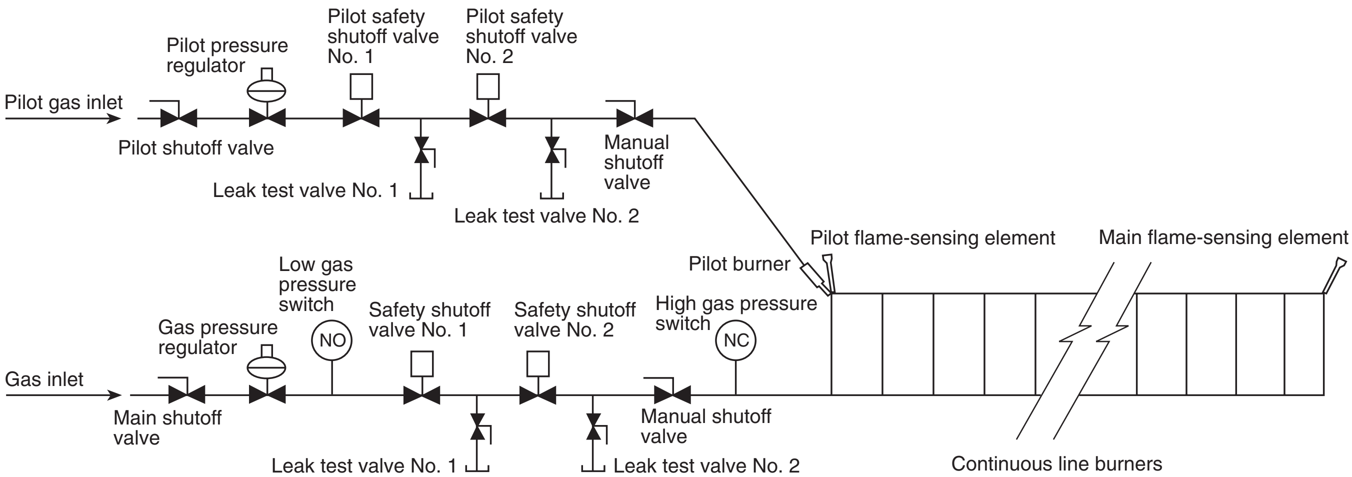


Figure A-5-9.2.2(b) An example of combustion safeguard supervising a group of radiant-cup burners having reliable flame-propagation characteristics from one to the other by means of flame-propagation devices.

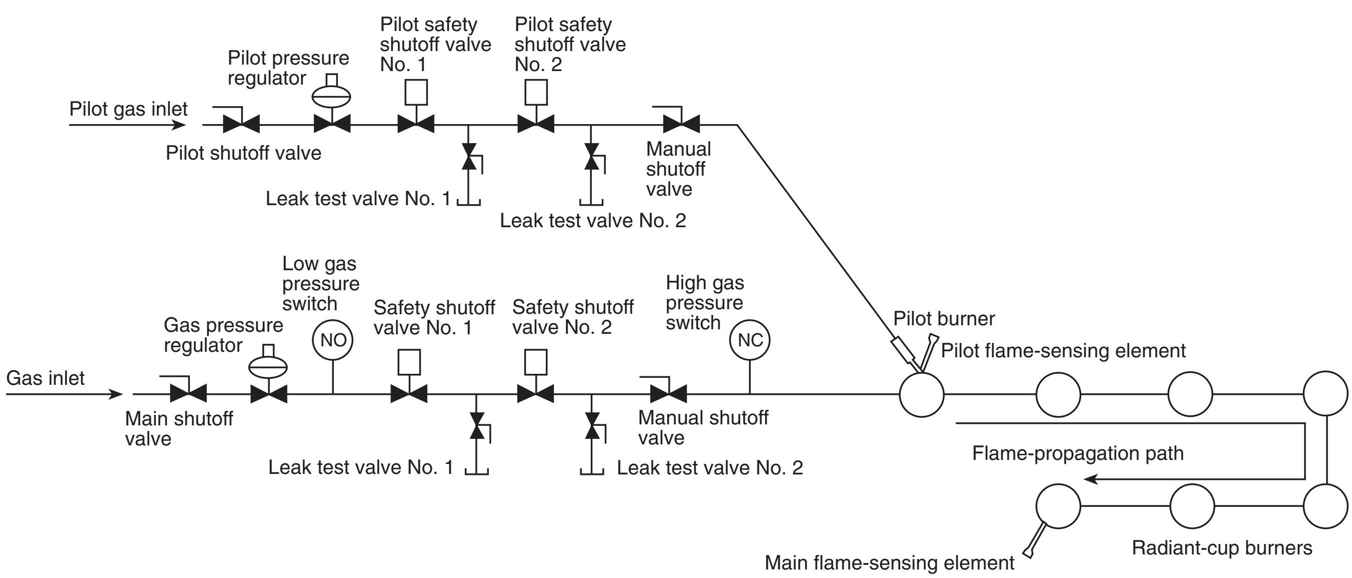


Table A-5-18.1.4 Heater Ratings

Control Device	Resistance-Type Heating Devices		Infrared Lamp and Quartz Tube Heaters	
	Rating (% of Actual Load)	Permitted Current (% of Rating)	Rating (% of Actual Load)	Permitted Current (% of Rating)
Fusible safety switch (% rating of fuse employed)	125	80	133	75
Individually enclosed circuit breaker	125	80	125	80
Circuit breakers in enclosed panelboards	133	75	133	75
Magnetic contactors				
0–30 amperes	111	90	200	50
30–100 amperes	111	90	167	60
150–600 amperes	111	90	125	80

Note: The above applies to maximum load or open ratings for safety switches, circuit breakers, and industrial controls approved under current NEMA standards.

A-5-18.2 See Section A-5-16.

A-5-19 See Section A-5-16.

A-5-19.2 Interrupting the flow of heat transfer fluid to an oven can be accomplished by shutting down the central fluid heating system or by shutting a heat transfer fluid safety shutoff valve on both the oven supply and return lines. If heat transfer fluid safety shutoff valves are used, the central fluid heating system may need an automatic emergency loop to provide a dummy cooling load and to maintain fluid flow through the heater.

A-5-20.2 Types of Indicating and Recording Vacuum Gauges. The calibration of all vacuum gauges should follow the standards specified by the American Vacuum Society.

Mechanical Gauges. The bellows and diaphragm mechanical gauges operate on a differential between atmospheric and process pressure. They are compensated for atmospheric pressure changes and calibrated for absolute pressure units. They are not suited for high-vacuum work, being limited to approximately 1 mm Hg (133 Pa) absolute. Readout is approximately linear except when calibrated in altitude units. Electrical output is available.

McLeod Gauge. For high-vacuum work, the McLeod gauge is often used as a primary standard for the calibration of other, more easily used instruments. The gauge is limited to intermittent sampling rather than continuous use. It operates on the principle of compressing a large known volume (V_1) of gas at unknown system pressure (P_1) into a much smaller volume (V_2) at a known higher pressure (P_2). As derived from Boyle's Law, at constant temperature,

$$P_1 = \frac{P_2 V_2}{V_1}$$

The gauge then is calibrated to read P_1.

Thermal Gauges. The operation of a thermal gauge is based on the theory that energy dissipated from a hot surface is proportional to the pressure of the surrounding gas. Some manufacturers produce thermal gauges that are subject to contamination by vaporized materials, and this issue should be discussed with the gauge manufacturer.

(a) *Thermocouple Gauge.* The thermocouple gauge contains a V-shaped filament with a small thermocouple attached to the point. At low absolute pressures, the cooling effect on the heated filament is proportional to the pressure of the surrounding gas. Therefore, the thermocouple electromagnetic field (emf) can be used to indicate pressure. In order to compensate for ambient temperature, an identical second unit is sealed in an evacuated tube. The differential output of the two thermocouples is proportional to the pressure.

(b) *Pirani Gauge.* The Pirani gauge employs a Wheatstone bridge circuit. This circuit balances the resistance of a tungsten filament sealed off in high vacuum against that of a tungsten filament that can lose heat to the gas being measured by means of conduction. In the Pirani gauge, the resistance of the filament, rather than its temperature, is used as an indication of pressure.

(c) *Bimetal Gauge.* A bimetallic spiral is heated by a stabilized power source. Any change of pressure causes a change of temperature and, therefore, a deflection of the spiral, which is linked to a pointer on a scale that indicates pressure.

Ionization Gauges. The two types of ionization gauges are the hot filament (hot cathode) gauge and the cold cathode (Phillips or discharge) gauge. Their principle of operation is based on the fact that collisions between molecules and electrons result in the formation of ions. The rate of ion formation varies directly with pressure. Measurement of the ion current can be translated into units of gas pressure.

(a) *Hot Filament Gauge.* This gauge is constructed like an electron tube. It has a tungsten filament surrounded by a coil grid, which, in turn, is surrounded by a collector plate. Electrons emitted from the heated filament are accelerated toward the positively charged coil grid. The accelerated electrons pass through the coil grid into the space between the grid and the negatively charged collector plate. Some electrons collide with gas molecules from the vacuum system to produce positive ions. The positive current is a function of the number of ions formed and, therefore, is a measure of the pressure of the system.

Ionization gauge–sensing elements are extremely delicate and should be handled carefully. Their filaments can burn out if accidentally exposed to pressures above 1×10^{-3} mm Hg (1.3×10^{-1} Pa) absolute. The advantages of this type of gauge are high sensitivity and the ability to measure extremely high vacuums.

(b) *Cold Cathode Gauge.* A cold cathode gauge employs the principle of the measurement of an ion current produced by a discharge of high voltage. Electrons from the cathode of the sensing element are caused to spiral as they move across a magnetic field to the anode. With this spiraling, the electron mean-free path greatly exceeds the distance between electrodes. Therefore, the possibility of a collision with the gas molecules present is increased, producing greater sensitivity (due to greater ion current) and thus sustaining the cathode discharge at lower pressure (i.e., high vacuum).

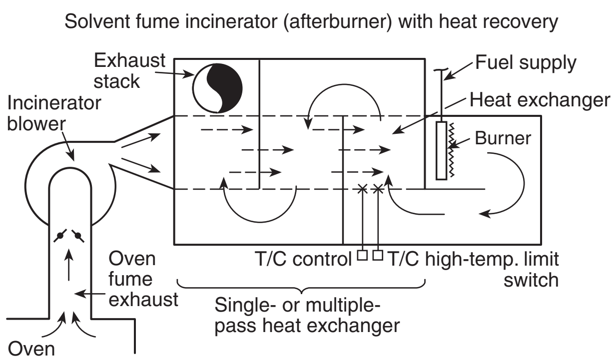
The sensing elements are rugged and are well-suited to production applications where unskilled help might make filament burnout a problem.

A-6-1.1 Afterburner or fume incinerator systems might or might not employ catalysts or various heat exchange devices to reduce fuel usage.

Structural supports, thermal expansion joints, protective insulation for incinerator housings, stacks, related ductwork, and heat recovery systems utilizing incinerator exhaust gases should be designed for operating temperatures of 450°F to 2000°F (232°C to 1093°C).

A-6-2 Fume incinerators should operate at the temperature necessary for the oxidation process and in accordance with local, state, and federal regulations. Fume incinerators or afterburners should control atmospheric hydrocarbon emissions by direct thermal oxidation, generally in the range of 1200°F to 2000°F (650°C to 1093°C). Figure A-6-2 shows a solvent fume incinerator with heat recovery.

Figure A-6-2 Example of direct thermal oxidation incinerator (afterburner) with primary heat recovery.



A-6-2.1 An individual fume source, or multiple sources that feed into one fume incinerator, might cause additional hazards if fed into an operating incinerator during the purge cycle of the source. *(See 5-4.1.3.)*

A-6-2.2 Operating controls should be configured to minimize the likelihood of an excess temperature condition being caused by one or more of the following:

(1) Reduction or termination of fuel to the fume incinerator burner
(2) Interruption of the fume-generating process
(3) Dilution of hydrocarbon concentration with fresh air
(4) Partial emission stream bypass of the heat exchanger

A-6-4 Catalytic fume incinerators should operate at the temperature necessary for the catalytic oxidation process in accordance with local, state, and federal regulations.

Catalytic fume incinerators control atmospheric hydrocarbon emissions by thermal oxidation, using a catalyst element. Oxidation occurs at or near the autoignition temperature of the contaminants, which ranges from 450°F to 950°F (232°C to 510°C).

Catalyst elements utilize various types and forms of substrates such as the following:

(1) Metal shavings
(2) Small, irregular, metal castings
(3) Formed or stamped light gauge sheet metal
(4) Ceramic- or porcelain-formed structures, pellets, or granules

Most substrates are restricted to fixed bed applications, although pellets and granules have application in fluidized beds as well. Various catalyst materials are available and include rare earth elements, precious metals such as platinum and palladium, or a few metallic salts. For commercial use, the catalyst material is bonded to or mixed in with (in the case of ceramic or porcelain structures, pellets, or granules, etc.) the substrates specified in (1) through (4).

For atmospheric pollution control, catalyst materials frequently are installed in oven exhaust streams, and the increased energy level resulting from hydrocarbon oxidation is either discharged to the outside atmosphere or recycled to the process oven, directly or by means of a heat exchange system.

The application of catalysts should recognize the inherent limitations associated with these materials, such as the inability to oxidize silicone, sulfur, and halogenated compounds (certain cataylsts employing base metals, i.e., manganese or copper, are known to be halogen- and sulfur poison–resistant) as well as metallic vapors such as tin, lead, and zinc. These materials can destroy catalyst activity, whereas various inorganic particulates (dust) can mask the catalyst elements and retard activity, thus requiring specific maintenance procedures. Consultation with qualified suppliers and equipment manufacturers is recommended prior to installation.

Where applicable, catalyst afterburner exhaust gases may be permitted to be utilized as a heat source for the process oven generating the vapors or some other unrelated process. Heat recovery can be indirect, by the use of heat exchange devices, or direct, by the introduction of the exhaust gases into the process oven.

Alternately, catalytic heaters may be permitted to be installed in the oven exhaust stream to release heat from evaporated oven by-products with available energy being returned by means of heat exchange and recirculation to the oven processing zone. *[See Figures A-6-4(a) and (b).]*

Figure A-6-4(a) Example of catalyst system independent of oven heater for air pollution control.

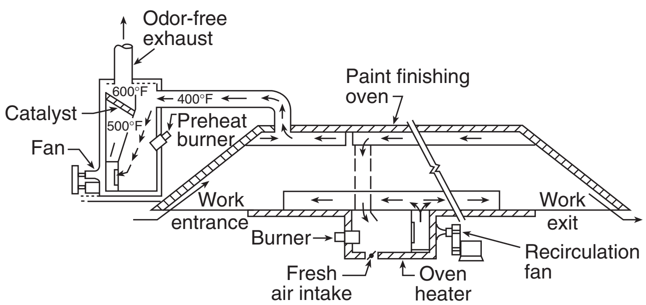
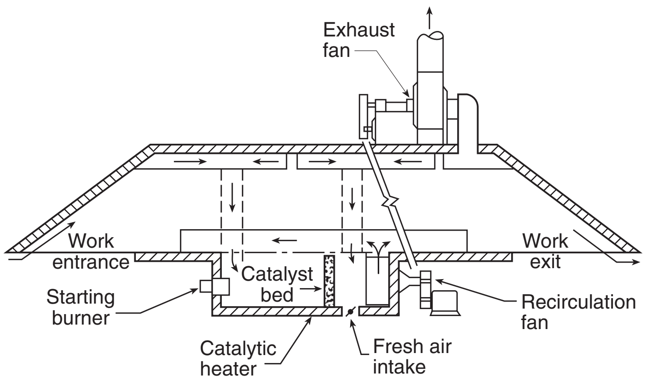


Figure A-6-4(b) Example of indirect-type catalytic oven heater for full air pollution control.



A-6-4.2 The temperature differential (ΔT) across the catalyst should be monitored to ensure that catalytic oxidation is occurring. Separate temperature-indicating instruments or controllers can be used to determine the ΔT arithmetically. Control of fuel or electrical energy for preheating the fume stream entering the catalyst can utilize temperature-measuring instruments at the catalyst inlet or discharge or at a juncture between instruments in each location. Maximum permitted afterburner temperature should be monitored only at the catalyst bed exit. The ΔT across the catalyst bed indicates the energy release and should be limited to values nondestructive to the catalyst material.

Regenerative catalyst oxidizers that employ flow reversal through the system do not produce a measurable ΔT across the catalyst bed indicative of the energy released from the oxidation of the combustibles. In regenerative catalytic oxidation systems, the flow is reversed frequently through the system to maximize utilization of process heat. One characteristic is that the measured temperature at any one point in the system's packed beds, whether in the heat matrix (ceramic packing) or in the catalyst bed, is never constant, rather a sinusoidal function of time. Measuring before and after the catalyst bed does not show energy released from volatile organic compound (VOC) oxidation. The fact that the catalyst bed is employed for VOC oxidation and heat recovery means that those temperatures measured are dependent on flow rate, duration between flow reversals, concentration of VOC, VOC species, activity of catalyst, and burner input.

A-6-4.3 Concentrations at 25 percent LEL can produce a temperature rise near 600°F (316°C) that, where added to the required inlet temperature, results in temperatures generally considered to be within a range where thermal degradation occurs.

In the event there is a high-temperature shutdown of the system, the catalyst bed will need to be cooled to prevent further damage of the catalyst through thermal or high-temperature breakdown. Most catalysts employ a high surface area substrate like alumina that allows for the maximum amount of catalyst material exposed to the fumes per unit of catalyst (pellet, granule, or structured packing). The surface area of the catalyst can be diminished through failure of the pore structure of the substrate at elevated temperatures [typically greater than 1200°F (649°C)], which results in less exposed catalyst material per unit of catalyst and a lower activity. This rate of thermal poisoning is a function of temperature and duration, and the net effect can be minimized by quickly cooling the catalyst to safe operating temperatures, from 450°F to 950°F (232°C to 510°C).

A-6-4.4 Oxidation performance of catalyst material is a function of temperature, velocity, and pressure drop (ΔP) through the bed, with bed size and configuration directly related to these factors. Pressure drop across the bed fluctuates with temperatures and particulate contamination. Contamination can lead to reduced safety ventilation in the upstream process.

A-6-4.5 Although the definition of a catalyst is a substance that participates in a chemical reaction without being changed by it, the reality is that catalysts are affected by chemical reactions and will lose their ability to promote the desired chemical reaction over time. In order to be sure that a catalytic fume incinerator is performing as intended, it is necessary to periodically check the activity of the catalyst. The usual method for doing this is to send a sample of the catalyst to the supplier for testing. The need for obtaining these samples should be addressed in the design of the catalyst bed.

The consequence of declining catalyst activity is the incomplete destruction of the organic vapor. Among the products of a partial combustion reaction are hydrogen, carbon monoxide, and aldehydes, all of which are flammable. The impact of significant quantities of these flammable gases on the operation of a direct heat recovery system should be assessed by the equipment supplier. Other potential concerns include the odor and skin irritation that can be caused by the aldehydes.

A-7-1 General Requirements. Integral liquid quench systems might be constructed within the furnace vacuum chamber or might be in quench vestibules separated from the heating portion of the chamber with a door or vacuumtight valve. Semicontinuous furnaces employ valves on each end of the hot vacuum zone. These furnaces might be divided into three separate chambers: a loading vestibule, a hot vacuum chamber, and a cooling vestibule. With this arrangement, cooling or pressurizing the hot vacuum chamber is not required for loading and unloading. Cooling vestibules are often equipped with elevators so that loads can be quenched by either vacuum, gas, or oil.

A-7-2.2 Although carbon steel plate has been used for many years with water cooling, its use is now not permitted, because corrosion is continuous and its extent is difficult to determine. In existing installations where carbon steel has been used with water-based coolants, the wall thickness should be tested periodically to determine the corrosion rate and predict the remaining life.

A-7-4.1 Quench medium tanks generally utilize a cooling system to maintain the quench medium at an operating temperature to reduce the quantity of quench media required. Three basic cooling systems are in general use and consist of the following:

(1) Internal cooler, where a heat transfer medium is circulated through a heat exchanger within the quench tank

(2) External cooler, where a quench medium is withdrawn from a quench tank, circulated through a water-cooled heat exchanger, and returned

(3) External cooler, where a quench medium is withdrawn from a quench tank, circulated through an air-cooled heat exchanger, and returned

A-8-1.1 The LEL for hydrogen is 4 percent in air. This represents a pressure of 30 torr (3.9 kPa). In the interest of safety, a lower limit of one-half of this pressure [15 torr (1.9 kPa)] has been used. Other gases have other LELs. *(See Appendix F.)*

A-8-1.2 Flammable gaseous hydrocarbons, dissociated ammonia, and hydrogen are frequently employed either at pressures below atmosphere or slightly above atmosphere, which should be considered in the design of the furnace.

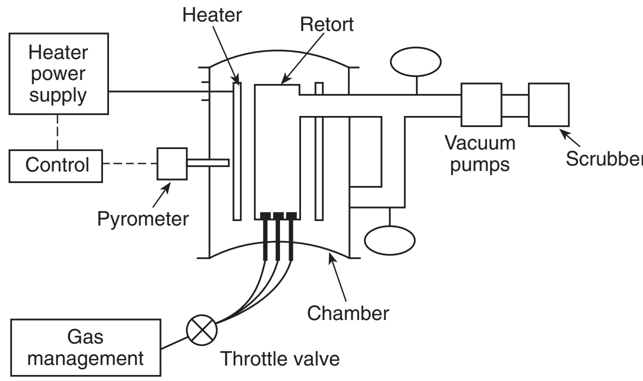
General. Chemical vapor deposition (CVD) is a process of reacting gaseous constituents to form a film on a surface. It can be used to produce thin films, thick films, or monolithic structures. In a typical CVD process, the gaseous reactants, usually involving halides, are injected into a heated volume at reduced pressure where they react to form a solid material plus gaseous by-products that might be corrosive, toxic, or flammable.

Furnace. Hot-wall furnace designs are employed using muffles of alloy suitable for the temperature and corrosion conditions encountered at temperatures up to 1832°F (1000°C). Heating is by an external electric furnace capable of uniform reproducible temperature control. Quartz muffles are employed where demanded by corrosion conditions and where the scale of the operation is sufficiently small to enable the degree of care and delicate handling necessary to avoid breakage.

Reaction temperatures above 1832°F (1000°C) necessitate cold-wall furnace technology, with most furnaces utilizing graphite hot zones. If the CVD reaction involves a product that can damage the heating element or impair the efficiency of the insulation, or both, a graphite muffle with inert pump-out and gas injection provisions is used in conjunction with gas blanketing outside to ensure that the reactants are confined. *(See Figure A-8-1.2.)*

Vacuum System. CVD reaction pressures that range from 0.5 torr to 500 torr (66.66 kPa to 66.661 kPa) employ rotary mechanical oil-sealed pumps, often in series with a mechanical blower. A throttle valve controlled by a vacuum gauge that should be corrosion resistant and capable of measuring total absolute pressure regardless of composition maintains the desired pressure in the reaction chamber.

Figure A-8-1.2 Example of high-temperature CVD system.



Operating conditions can severely limit pump life in a variety of mechanisms, which include any of the following:

(1) Oil sludging and loss of lubricity
(2) Corrosive attack, usually with hydrochloric acid
(3) Abrasion from tramp deposition product

Several means of combating these rigorous conditions are available, depending on the specifics of the materials involved.

Gas Management. Gases in controlled quantity may be permitted to be delivered to the reaction chamber by means of rotameters with needle valves in basic systems, or alternatively, by electronic mass flow controllers and readouts in systems that can employ programmable control. Typically, three gas components are involved:

(1) Precursor, which contains the element or compound to be deposited
(2) Reducer, such as hydrogen or ammonia
(3) Diluent, such as argon or nitrogen, to influence structure, density, or other characteristics of the deposit

Particular care should be exercised to ensure that the reactor is in the proper operating mode prior to the introduction of gases. Purging connections adjacent to the gas supply connections prevent escape into the shop environment when the system is opened.

Handling By-Product. A common reaction by-product is hydrogen chloride (HCl) gas. Optimum system design avoids hydrolyzing until it reaches a trap or a scrubber where it can be neutralized. Toxic and corrosive constituents are burned or captured chemically, as appropriate.

Special Furnace Requirements. Requirements for the furnace design for CVD service should include the following:

(1) Use of austenitic stainless steel interior surfaces of the chamber
(2) Avoidance of nonferrous metals in valves and piping that might be exposed to reactants and by-products
(3) Provision of adequate clamping of access closures to avoid leakage where operating near atmospheric pressure
(4) Provision of pressure-relief devices such as corrosion-resistant relief valves or properly vented rupture discs
(5) Provision of NFPA-approved auxiliaries where operating with flammable mixtures

A-8-2.6 If a residual amount of air is retained in an external chamber, the inadvertent opening of a valve to an external system in the presence of a flammable atmosphere could create an explosive mixture.

A-8-2.12 Cracking of a sight glass, which is not unusual, can admit air into the chamber or allow flammable gas to escape.

A-8-5 In case of electric power failure, all the following systems can be expected to stop functioning:

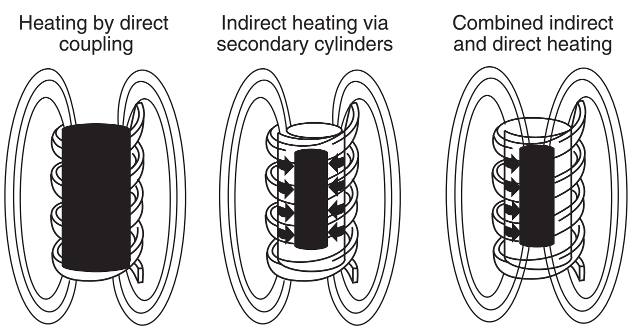
(1) Heating system
(2) Flammable atmosphere gas system
(3) Vacuum pumping system

A-9-1.1 Locations for tanks and cylinders containing flammable or toxic gases shall be selected with adequate consideration given to exposure to buildings, processes, storage facilities, and personnel.

A-9-2 Special reference should be made to ANSI K61.1, *Storage and Handling of Anhydrous Ammonia*.

A-10-1 Induction heating is the heating of a nominally conductive material by its own I^2R power when the material is placed in a varying electromagnetic field. Heating can be direct by coupling, indirect by a secondary cylinder or susceptor, or by a combination of both of these methods. *(See Figure A-10-1.)*

Figure A-10-1 The three induction heating methods.



A-10-2.2 The bottom one-third of a water-cooled vessel of a vacuum induction melting furnace should be trace-cooled instead of jacketed to provide minimum water storage in the event of a melting crucible breakthrough.

The bottom of the furnace chamber should be equipped with a separate cooling circuit that can be valved off in the event of a molten metal burn-through of the chamber.

The quality of the cooling water should be considered to minimize plugging of the induction coil or coils and to minimize corrosion or attack of all water-cooled components.

A-10-3 The purpose of the power supply is to transform the power line to a suitable voltage and current (and, where necessary, to convert from 60 Hz to another frequency) to energize the induction coil. Consideration should be given to furnishing the power supply with a means of proportioning control.

Generally, this is accomplished with either a motor generator, an electronic oscillator, or silicon-controlled, solid-state converter units. In most cases, a dc control signal is provided for proportioning control. The design of the power supply is specific to the individual furnace and size.

The power supply can include a transformer (or a motor generator), capacitors with control switches as necessary, a control device such as a saturable core reactor, primary fuses or circuit breakers for electrical protection, and an electrical disconnect switch for service. A power controller may be permitted to be used where necessary to accept a signal from the furnace temperature controller.

The power supply output voltage should be limited to a maximum of 80 volts for noninsulated induction coils in order to prevent electrical breakdown or internal furnace arcing. As the atmospheric pressure is reduced in the vacuum chamber, arcing voltage changes. This voltage change is a function of electrical spacing and pressure. This function is not linear but has a minimum value for most gases used as cooling or partial pressure media in vacuum furnaces. If the voltage stress and mean-free path relationship reaches a critical value, corona discharge and arcing commences as a result of the field emission of electrons. For insulated induction coils, the operating voltage may be permitted to be higher in accordance with the dielectric of the insulating media chosen by the designer.

Assuming the use of a three-phase power line, consideration should be given to provide balanced line currents across all three phases as a result of the induction coil load.

A-10-3.3 The design of the induction coil generally is circular and wound from copper tubing, allowing water-cooling of the coil.

The design of the induction coil should be considered carefully for proper match of impedance between the power supply, the coil, and the susceptor or work load.

The induction coil power terminal and vessel feed-through design should be considered for vacuum integrity and induction heating effects.

Generally, the feed-through flange should be of electrically nonconductive material, and the power feed-through leads should be grouped in close proximity.

A-10-3.4 In the event of contact, electrical short circuits can result in major damage to the induction coil, charge, or furnace parts.

A-10-3.7 In many applications, the induction coil is thermally insulated from the susceptor or work load to prevent high temperature radiation or heat damage.

A-10-4.5 Separate indicator lights for malfunctions should be installed in the control circuit to indicate malfunctions. Light circuits should be reset by separate pushbutton switches when the malfunction has been corrected.

A-11-1 Before entering any equipment or confined space, all applicable regulations should be referenced. In particular, reference should be made to ANSI Z117.1, *Safety Requirements for Confined Spaces*.

Authoritative references include NIOSH *Pocket Guide to Chemical Hazards* and the annual TLVs—*Threshold Limit Values for Chemical Substances in the Work Environment*.

A-11-2 Maintenance Checklist.

General. A program of regular inspection and maintenance of the vacuum furnace is essential to the safe operation of the equipment and should be instituted and followed rigorously. Basic heating devices, such as heating elements or induction coils, should be designed for ease of maintenance. If special tools are needed, they should be supplied by the furnace manufacturer.

Vacuum System. Mechanical vacuum pumps should be checked and repaired as necessary. The following is a partial list:

(1) Drive belts are not worn.
(2) Drive belt tension is proper.
(3) No oil leaks are at the shaft seals.

(4) Oil level is correct.
(5) Oil is free of dirt and water accumulation.
(6) Drip legs are drained.
(7) Mounting bolts are tight.
(8) Vacuum lines and vibration couplings are tight.

The high vacuum diffusion pump should be checked and repaired as necessary. The following is a partial list:

(1) Waterflow for cooling is correct.
(2) Heating elements are tight and indicate proper electrical parameters.
(3) Oil level is correct.
(4) Oil is not contaminated.

Control vacuum valves should be checked and repaired. The following is a partial list:

(1) Air supply filter is drained and operating.
(2) Air supply oiler is filled to correct level and operating.
(3) Pilot valves are not leaking excess air.
(4) Moving O-ring seals are cleaned or changed where excess wear is indicated.

Numerous stationary and moving vacuum seals, O-rings, and other rubber gaskets are associated with the main vacuum vessel. These seals should be inspected properly to ensure cleanliness, freedom from cracks or gouges, and retention of elasticity. The main front and rear door, or bottom head, where work regularly passes, should receive particular attention.

Hot Zone (Resistance Heaters) — Power Supply. The power supply should be inspected and corrected as required. The following is a partial list:

(a) Primary and secondary wiring and cables are tight and free from overheating.

(b) Proper ventilation and air cooling or proper waterflow per unit or transformer is present.

(c) Control relays or contactors are free of contact pitting or arcing, which could result in contact welding.

(d) Power supply voltage is maintained within reasonable limits to ensure against overloading.

NOTE: Undervoltage can result in operational failure of any one of the numerous vacuum furnace systems.

Hot Zone (Resistance Heaters) — Thermocouples. A regular replacement program should be established for all control and safety thermocouples.

It should be noted that the effective life of thermocouples varies depending on the environment and process, the temperature, and the vacuum, and these factors should be considered in setting up a replacement program.

Hot Zone (Resistance Heaters) — Instrumentation. Temperature and vacuum instrumentation should be set up on a regular calibration and test schedule.

Many components of the vacuum furnace are required to be water-cooled. Drain lines should be inspected for proper flow and temperature of the cooling water. Pressure regulators, strainers, and safety vents should be inspected for proper setting and maintained free from dirt and contamination.

If an evaporative cooling tower is integral to the furnace system, the tower should be cleaned, the motor and bearings greased, and the water strainer cleaned on a regular basis.

Hot Zone (Resistance Heaters) — Interlocks and Alarms. Periodic checks of all safety interlocks and alarms should be performed. Particular attention should be given to overtemperature safety devices, low air pressure, insufficient cooling water, and vacuum, oil temperature, and low oil alarms.

(1) The following continuous observations should be made:
   a. Review auxiliary vacuum instrumentation for proper indication of system performance (i.e., foreline, holding pump, mechanical pump, and diffusion pump operating temperature).
   b. Review power instrumentation and trim or zone control settings.
   c. Check instrumentation for “on conditions,” chart paper, and active operation.
   d. Check oil level in mechanical pumps and diffusion pump.
   e. Check mechanical vacuum pump, blowers, gas fans, and oil pumps for unusual noise or vibration. Review V-belt drive, belt tension, and belt fatigue.
   f. Check quench gas pressure and available capacity.
   g. Check for proper operation of ventilation equipment if required for the particular installation.
(2) The following regular shift observations should be made:
   a. Review auxiliary vacuum instrumentation for proper indication of system performance (i.e., foreline, holding pump, mechanical pump, and diffusion pump operating temperature).
   b. Review power instrumentation and trim or zone control settings.
   c. Check instrumentation for “on conditions,” chart paper, and active operation.
   d. Check oil level in mechanical pumps and diffusion pump.
   e. Check mechanical vacuum pump, blowers, gas fans, and oil pumps for unusual noise or vibration. Review V-belt drive, belt tension, and belt fatigue.
   f. Check quench gas pressure and available capacity.
(3) The following weekly checks should be made:
   a. Review hot zone for normal condition of heating elements, heat shields or retainers, insulators, and work support or mechanism.
   b. Test thermocouples and lead wires for broken insulators, shorts, and loose connections.
   c. Test visible or audible alarms for proper signals.
(4) The following monthly observations should be made:
   a. Test interlock sequence of all safety equipment. Make each interlock fail manually, verifying that related equipment shuts down or stops as required.
   b. Inspect all electrical switches and contacts, and repair as required.
   c. Test all temperature instrument fail-safe devices, making certain that the control instrument or recorder drives in the proper direction.
   d. Clean all water, gas compressor, and pump strainers.
   e. Test automatic or manual turndown equipment.
   f. Change mechanical pump oil and diffusion pump oil, if necessary.
   g. Test pressure-relief valves, and clean if necessary.
   h. Inspect air, inert gas, water, and hydraulic lines for leaks.
(5) The following periodic maintenance checks and procedures should be made. The frequency of these checks and procedures depends on the equipment manufacturer’s recommendations:

a. Inspect vacuum chamber O-ring and other gaskets for proper sealing.
b. Review the vacuum chamber vessel for evidence of hot spots that indicate improper water cooling.
c. Review furnace internals in detail for heating element, heat shield, and work support or mechanism failure or deterioration.
d. Lubricate instrumentation, motors, drives, valves, blowers, compressors, pumps, and other components.
e. With brush or other devices, remove major buildup of oxides and contamination from the hot zone and accessible areas of the cold-wall chamber. Blow out contaminate with a dry air hose.
f. Run furnace to near maximum design temperature and maximum vacuum to burn out furnace contamination.
g. Install new exhaust valve springs and discs and clean and flush oil from the mechanical vacuum pumps. Replace springs and O-rings in the gas ballast valves.
h. Run a blank-off test for the mechanical vacuum pump to ensure process parameters are met.

A-12-1 General. Hydrogen fires normally are not extinguished until the supply of hydrogen has been shut off because of the danger of reignition or explosion. In the event of fire, large quantities of water are sprayed on adjacent equipment to cool the equipment and prevent its involvement in the fire. Combination fog and solid-stream nozzles are recommended to allow the widest adaptability in fire control. Small hydrogen fires are extinguished by dry chemical extinguishers or with carbon dioxide, nitrogen, and steam. Reignition can occur if a metal surface adjacent to the flame is not cooled with water or by other means. The various conditions under which gaseous hydrogen is stored at consumer sites, including unattended installations, necessitates coordination between the supplier, the consumer, and the authority having jurisdiction for adequate and reliable fire protection of the system.

Appendix B Pump Data

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 The pump ranges given in Table B-1 and Figure B-1(a) show approximate minimum commercial absolute pressure capabilities of the principal types of vacuum pumps. Figures B-1(b) through (d) show typical vacuum system arrangements.

Table B-1 Pump Ranges

Type of Pump	Range of Vacuum
Centrifugal or reciprocating mechanical	760 torr to 10 torr (101 kPa to 1.3 kPa)
Steam ejector	760 torr to 0.050 torr (101 kPa to 6.7 Pa)
Rotary oil-sealed mechanical	760 torr to 0.050 torr (101 kPa to 6.7 Pa)
Blowers (mechanical boosters)	1 torr to .001 torr (133 Pa to 1.3×10^{-1} Pa)
Oil ejector	0.5 torr to .001 torr (66 Pa to 1.3×10^{-1} Pa)
Diffusion	0.300 torr to 10^{-7} torr (40 Pa to 1.3×10^{-5} Pa)
*Cryogenic devices (i.e., liquid nitrogen cold traps)	0.001 torr (1.3×10^{-1} Pa)
*Getter	0.001 torr (1.3×10^{-1} Pa)
Ion molecular	0.001 torr (1.3×10^{-1} Pa)

*Generally associated with small specialized systems.

Figure B-1(a) Pump ranges.

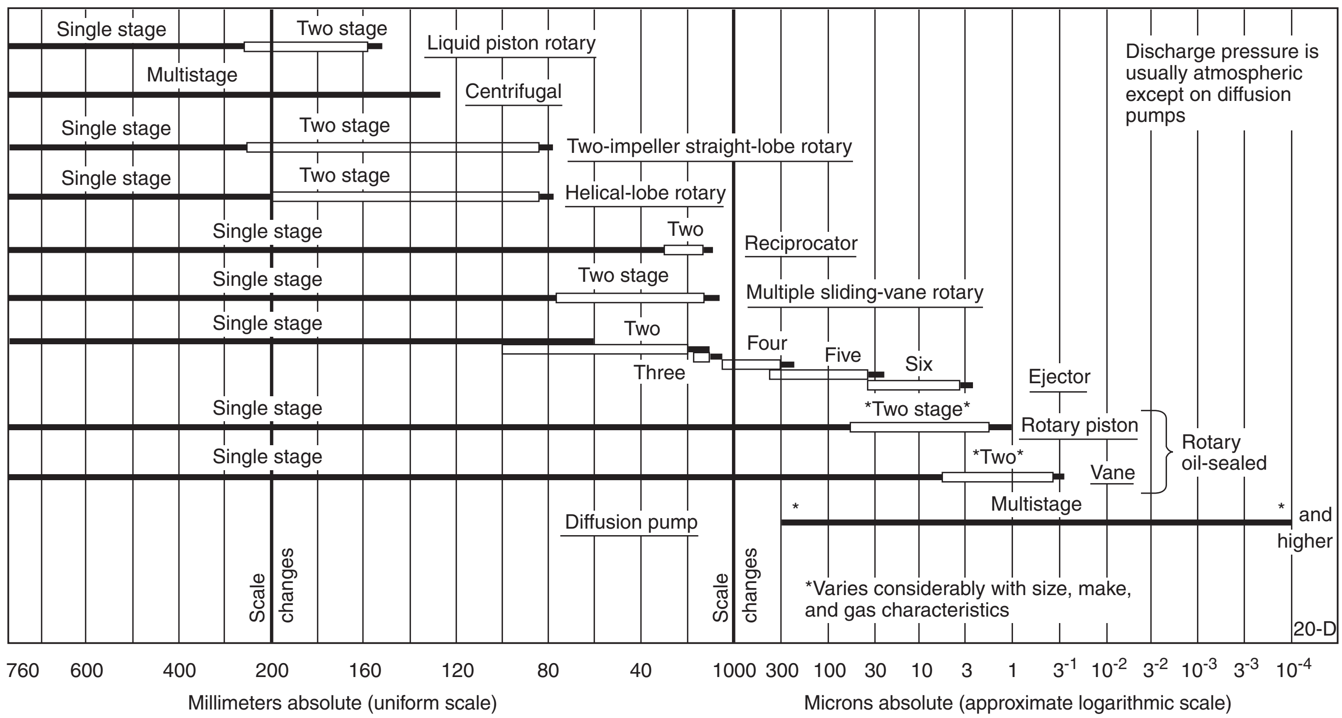


Figure B-1(b) Typical vacuum system.

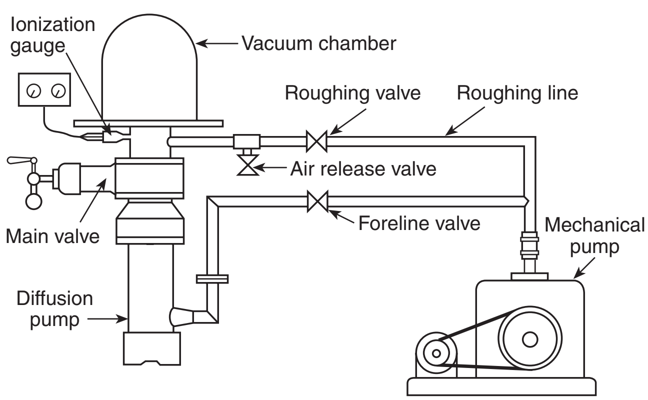


Figure B-1(c) How a diffusion pump works.